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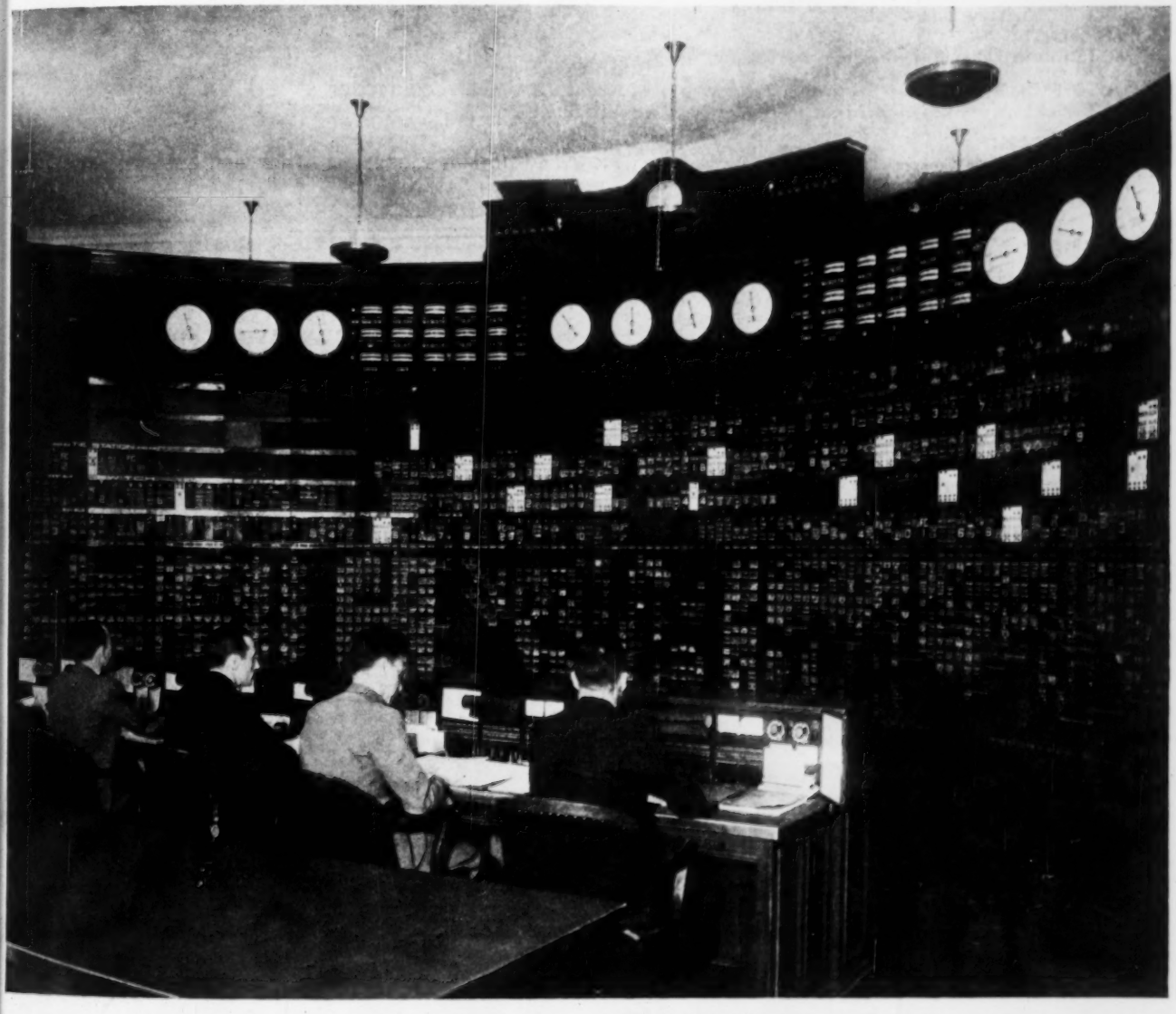
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT AND CONTROL

VOLUME 7 JULY, 1934 NUMBER 7



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(Courtesy *Electrical Engineering*—American Institute of Electrical Engineers)

INSTRUMENTS

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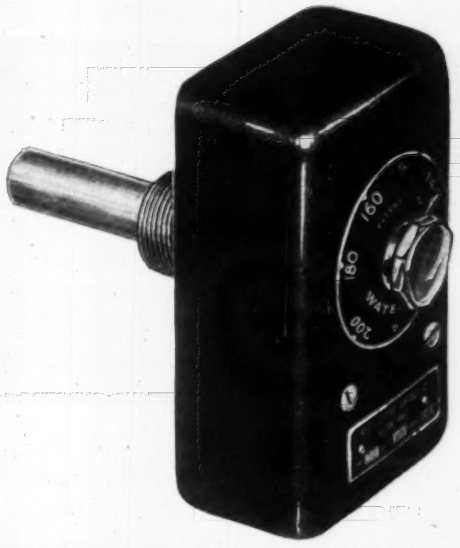

This Waterstat is only one of a complete line of control devices made by United Electric Controls Co., and using Burgess Micro Switches.

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BURGESS MICRO SWITCH

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C. F. BURGESS LABORATORIES, INC.

FREEPORT, ILLINOIS

EDITORIAL COMMENT

In This Issue

We shall publish every three or four months a review of important recent fluid metering progress articles to which few of our readers have access. The first correlated review appears this month. **L. M. Van der Pyl** is excellently equipped for this job of gathering, selecting, translating, reporting and interpreting.

The **Reynolds Number** completely characterizes the type of fluid flow and is of great value in flow meter work—if it is computed in such a way that g is eliminated. In our May issue F. J. Leerburger called attention to certain pitfalls which meter engineers must avoid if they want their R's not to be 32.2 times too big or too small. Whereupon four specialists sat down and wrote us four different but interesting comments, which we take pleasure in publishing.

Haven't you noticed how almost every time we publish a description of a special instrument for a highly specialized field, you get ideas for your own work in a radically different field? Such is the case again with the Forest Product Laboratory's **forest fuel hydrograph.** It certainly seems to be highly perfected, but we remember some twenty years ago having to redesign an outdoor apparatus to make it "bird-proof" and we hope Uncle Sam's clever scientists at Madison haven't slipped up in that respect. To be sure, a *sudden* increase in the weight of the wooden rods can be noticed on the chart and allowed for by drawing the rest of the weight curve that much below, but such ex—beg pardon—*in*crements contain moisture and therefore lose weight until they, too, attain hygroscopic equilibrium. Our free advice: install an overhead protection to catch these ex—beg pardon—these *in*crements!

About six years ago, **A. L. De Leeuw,** veteran but ever-youthful consulting engineer, lecturer and machine designer, took part in a symposium on hardness measurement and resolved to design a semi-automatic tester that would give "numbers" with definite meanings. He did. Now he selects *Instruments* as the proper medium to announce it to the engineering world.

No engineer nowadays needs to be reminded of the economic bearing of power factor in connection with utilization of a.c. energy. **Measurements of phase angle,** therefore, are of vital importance in every industry and this month's instalment of our electrical measurement series should interest industrial engineers.

Book Reviews this month take up more columns than ever before.

Also, a record-breaking number of **Manufacturers' New Literature** items.

The Front Cover

To tell "the story back of the board" when the board is the most remarkable in the world, would require an illustrated technical article—so we refer you to "Load Totalizing in the New York Area" by F. Zogbaum of N. Y. Edison, in the June *Electrical Engineering.*

PRESIDENT ROOSEVELT, addressing the masses and classes over the radio a few nights ago, gave them an "administration report"—and us an idea. This idea is to present a brief account of *Instruments'* "administration" with regard to new products. The first "plank" in our "platform" is to strive to report ALL new devices of interest to you: Not one announcement of a new instrument has ever been thrown in the waste basket.

But—and here's where we lift the veil—if one manufacturer sends us a 2000-word description of a mere new model, we may boil it down to one brief paragraph; while if a second manufacturer brings out something wholly new but sends us only a one-paragraph announcement, we urge him to prepare an adequate engineering description with technical diagrams. If he does not do it, we sometimes do it at our own expense. One ideal, of course, might be to put all new products through examinations and tests, and print full engineering reports on design, construction and performance. This would require facilities like those of the National Bureau of Standards, or Underwriters' Laboratories; and one result would be a 400-page magazine you wouldn't have time to read!

On several occasions, though, we investigated new instruments and wrote them up in the New Instruments Section without consulting the makers' bulletins. It has even happened that we discovered and printed facts which the makers did not know.

To be sure, such a procedure is unusual. Nor do we desire all manufacturers to send us their new devices: it would be decidedly inconvenient to find the expressman delivering a ten-ton load of control systems, testing machines, spectrographs, etc. Anyway, it is not necessary: *Instruments* has been fortunate in establishing relations with instrument company development engineers, physicists and other technical men, with the result that we often get *exclusive* technical descriptions of new products, conservatively written for *you* by these modest specialists. The general run of items in the New Instruments Section, however, have to be written by *Instruments'* own engineering staff, and include such technical data as we are able to wheedle out of the manufacturers for your information.

Reportorial impartiality is our motto. As we declared on this page two years ago:

> *Instruments'* news pages are not for sale . . . The New Instruments Section is conducted solely for the information of our readers . . . Manufacturers' advertising appropriations could not buy a single inch of our news space.

President Roosevelt cleverly asked each individual listener to check for himself or herself the effects of his New Deal. In like manner we suggest that you check up the above for yourself by comparing our New Instruments Section with the new products sections of other technical journals. Thus you may be able to appreciate the work involved in reporting all new developments—part of *Instruments'* Service to You.

M. F. BEHAR

Recent German Work on The Proper Arrangement of a Metering Orifice

By LYMAN M. VAN DER PYL*

FLOW measurement has been an extremely active subject in recent European literature, principally in Germany. It was in 1930 that the Flow Meter Committee of the Verein deutscher Ingenieure, using the work of Witte[1] as a basis, published its standard of flow measurement[2] and the succeeding years have seen the appearance of many important papers on the subject, viewing it from both the theoretical and practical sides. Only six of these papers will be mentioned in this review, in which particular attention will be paid to the matter of the installation of orifices, especially with reference to the type of orifice specified by the German standard.

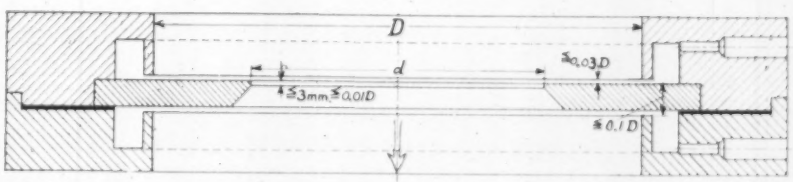

Fig. 1. The German standard orifice

It is necessary to consider first the design of this orifice; the required features are shown in Fig. 1. As may be seen at a glance, the principal difference from the orifices common in this country is in the type of pressure taps: the pressures are taken directly at the faces of the orifice plate. In the usual German design, the orifice plate is held between a pair of machined rings, which, in turn, are clamped between pipe flanges. Each of these rings contains an annular channel connected by a slit with the interior of the pipes, as shown; however, single taps at the faces of the plate may be used if desired. These "corner taps" resemble the flange taps more closely than any other type of taps used in this country, but the differential pressures obtained with the corner taps will be different from those obtained with flange taps under the same conditions, since the pressure changes rapidly as the fluid approaches and recedes from the orifice plate.

The German standard prescribes minimum lengths of straight pipe upstream and downstream from the orifice plate; these lengths differ for the single pressure taps and the annular rings, being somewhat lower for the latter. On the whole, the required lengths are not far from those recommended by the A.S.M.E.,[3] being sometimes greater and sometimes less. To be sure, no great difference is to be expected, since the purpose of the straight lengths of pipe is to allow space for the straightening-out of irregularities in the flow introduced by pipe fittings and similar disturbing elements, and approximately the same degree of straightening-out is necessary for all four types of primary elements of head meters.

The use of orifices as metering devices at the inlet and exist of pipes is not common in this country but is of interesting possibilities in certain connections. Stach has recently reported[4] the results of his tests on orifices installed under these conditions. These results, compared with the standard coefficients for an orifice installed in a pipe line, are shown in Fig. 2. As for the notation, m signifies the ratio of orifice to pipe area, α the standard discharge coefficient (which includes the velocity of approach), and α_i and α_e are the experimentally-determined coefficients for orifices in a pipe inlet and exit, respectively. With the orifice at the pipe exit, the coefficients are slightly higher than the standard figures for area ratios higher than 0.25, corresponding to diameter ratios higher than 0.5. With the orifice at the pipe inlet, the coefficient is independent of the size of the orifice and is constant at 0.60.

THIS is the first of a series of articles, each of which brings together the most recent foreign work on a particular sub-division of Instrumentation. Knowledge of foreign languages is but one of Mr. Van der Pyl's qualifications. His experiences since graduating *cum laude* from Harvard have included testing instruments at the Bureau of Standards, teaching chemistry at his Alma Mater, and doing research and development work with a tire and rubber company, a paper products manufacturer and an oil burner manufacturer. Since he joined "Emco" in 1927 the scope of his work has broadened to such an extent that he is today recognized in several fields of science and technology.

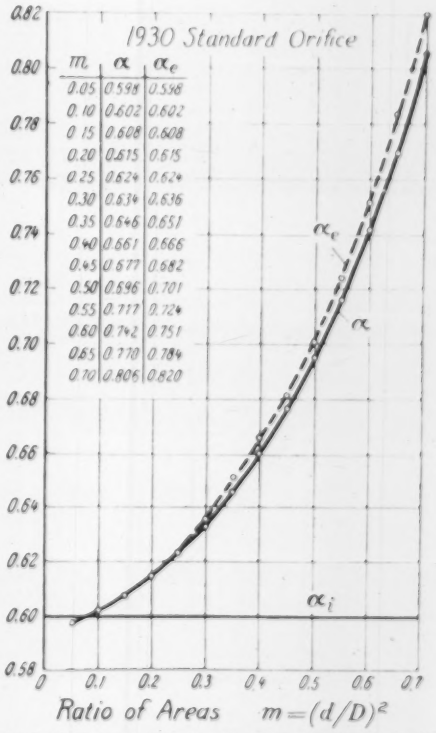

Fig. 2. Discharge coefficients of the German standard orifice installed at inlet and exit of pipes

*Pittsburgh Equitable Meter Co.

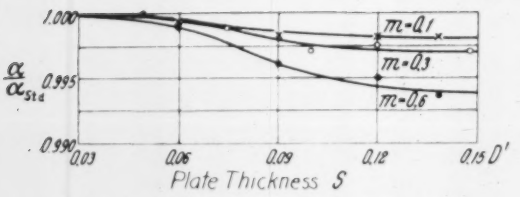

Fig. 3. Effect of plate thickness on the discharge coefficient

Possibly of greater interest to American flow meter engineers is the effect of conditions directly at the orifice. This subject has recently been covered in great detail by Kretzschmer and Wälzholz[5] who checked and extended the earlier results of Ruppel and Jordan.[6] All of the results of Kretzschmer and Wälzholz are given as the ratio of the experimentally-determined discharge coefficient α to the corresponding coefficient α_{std} given in the German standard.

Their results obtained in a test for determining the effect of the thickness of the orifice plate are shown in Fig. 3; D in this figure refers to the diameter of the pipe. The orifice was beveled on the downstream side and the thickness of the orifice plate was changed by machining away the downstream side, while the cylindrical section of the opening was held constant throughout the test. Thus, the effect of changing the plate thickness was to displace the downstream pressure tap, and the results check the experiments of Witte[7] on this subject.

Of course, gaskets are necessary between the orifice holding rings and the pipe flanges, and it is to be expected that irregularities will occur if they are not fitted properly. From consideration of the boundary layer of fluid it was reasoned that gaskets cut too small would have the least effect in large rough pipes with thin holding rings and the greatest effect in small smooth pipes with thick holding rings; this was checked experimentally. In addition it was found that the effect of the gasket increases with increasing ratios of area, which also might be expected. The results of the tests are shown in Fig. 4; the "limit of error occurring in service" marked on the figure is the error applying to the maximum projection of the gasket that would escape detection under ordinary conditions. From consideration of the figure it is evident that an eccentrically-installed gasket would behave like a gasket of small inside diameter, since the projecting part of the gasket tends to increase the coefficient while the receding part has but little effect.

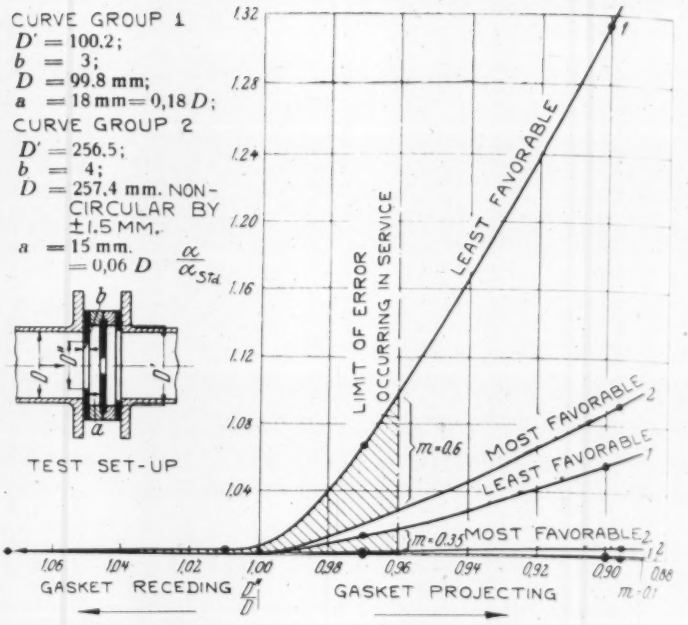

Fig. 4. Effect of gasket diameter on the discharge coefficient

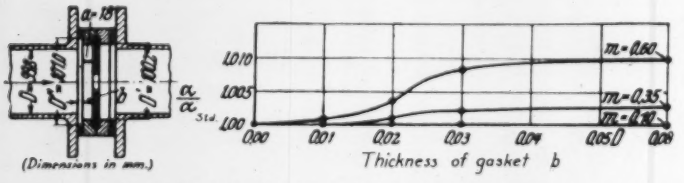

Fig. 5. Effect of gasket thickness on the discharge coefficient

The thickness of the gasket, as may be seen in Fig. 5, has considerably less effect on the coefficient than the gasket diameter, though this effect may be appreciable in small pipes. The curves apply to conditions that may be considered extreme.

It is to be expected that the diameter of the pipe will have an effect similar to that of the diameter of the gasket. Fig. 6 shows the results of tests with a pipe larger than the holding rings; a signifies the width of the holding ring while D' is the inside diameter of the holding ring. These tests were conducted with a smooth pipe and thus under the least favorable conditions.

It is, of course, conceivable that the inside diameter of the holding ring rather than the inside diameter of the pipe should be used in the calculation of the effect of the pipe diameter; if so, another error will be introduced: that involving the use of the wrong figure for the diameter in the meter

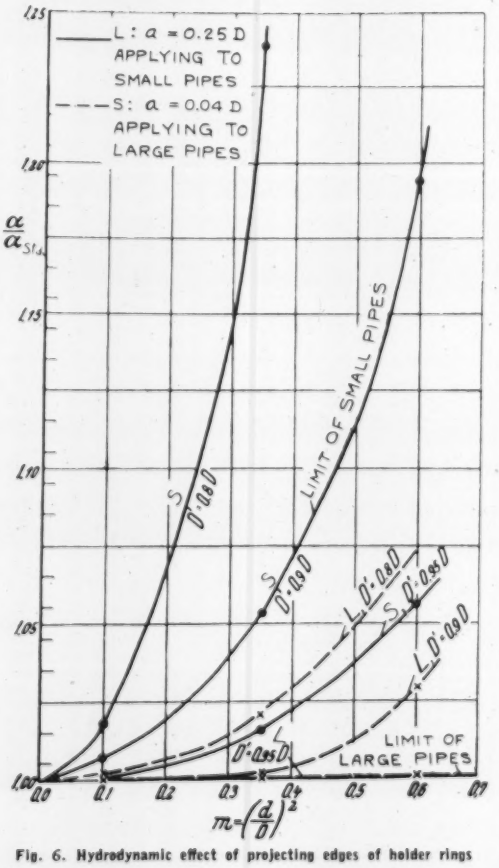

Fig. 6. Hydrodynamic effect of projecting edges of holder rings

calculations. Under such conditions, Fig. 7 is effective; the curves for $a = 0$ show the error due to the incorrect calculation alone, not including the hydrodynamic effect shown in Fig. 5. The notations of the limits for small and large pipes in Figs. 6 and 7 refer to the maximum discrepancy between pipe and plate holder diameters that might escape detection.

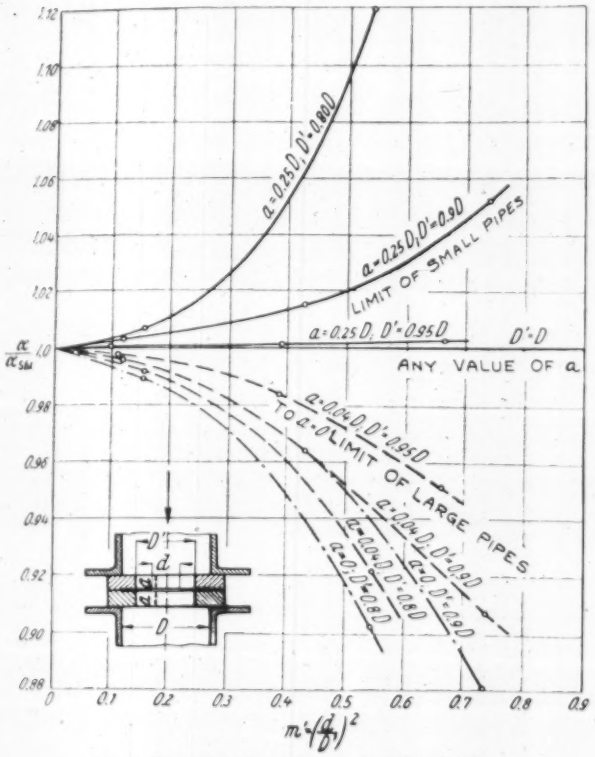

Fig. 7. Total effect of projecting edges of plate holders

In computing the total effect of these faults, Kretzschmer and Wälzholz took the average values between the most and least favorable curves in Fig. 5 to give the limits of the "range of possible error due to gasket" in Fig. 8; also the limit curves for small and large pipes in Fig. 7 were transferred to Fig. 8. The effects of other conditions were not included because these conditions are taken care of by the requirements or by specified tolerances in the German flow meter standards. In using this figure it should be noted that the maximum of the two effects is applicable and that the two effects are not additive; the reason for this is that only one of the effects can be completely operative at a given time.

Kretzschmer and Wälzholz refer to a type of orifice that will eliminate trouble from incorrectly-sized pipe; it is shown in Fig. 9. This orifice will not avoid errors due to thickness of gaskets, elliptical pipe or non-centered orifices, so that it has its limitations. Further, these authors suggest that trouble will be avoided when using small pipes (<100 mm.) if pipe sections adjacent to the orifice are smooth inside and of calibrated inside diameter. This, of course, is a worth-while precaution, since the effect of a given degree of wall roughness and of pipe irregularity is much greater in small than in large pipes.

All in all, an examination of the various figures, particularly Fig. 8, would suggest to some minds that the orifice is hardly an accurate measuring element. Nevertheless, it should be noted that although the installation

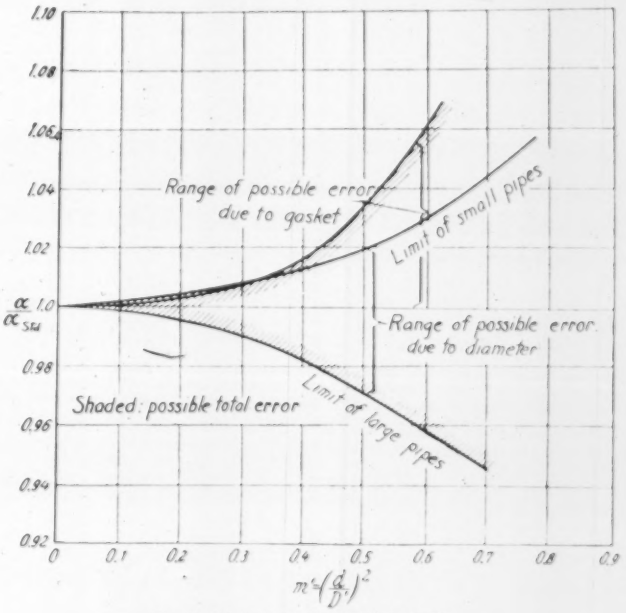
Range of possible error due to gasket
Limit of small pipes
Range of possible error due to diameter
Shaded: possible total error
Limit of large pipes
α/α_std
m'=(d/D')²

Fig. 8. Total effect of installations faults

faults discussed will cause trouble with the German standard orifice, corresponding faults will cause little or no trouble with American orifices using flange, vena contracta or pipe taps. Accordingly, and in spite of the apparently increasing acceptance of the German standard orifice by Continental European engineers, the recent work of Kretzschmer and Wälzholz makes it seem unlikely that the German type of pressure tap will ever gain wide adoption here. This being so, the writer may conclude by reporting that this opinion is shared by a distinguished American authority on orifice metering, as expressed emphatically in a private conversation only a few weeks ago.

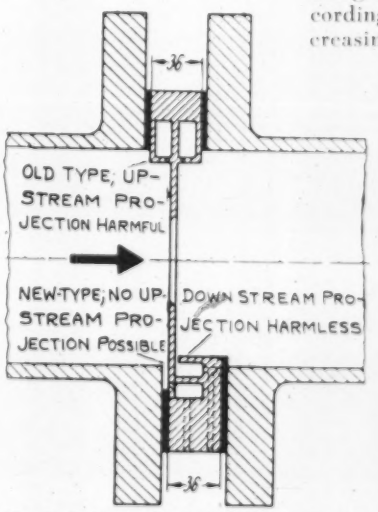

Fig. 9. Orifice reported to be insensitive to some disturbing factors

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[1]Witte. Durchflusszahlen von Düsen und Staurändern. *Technische Mechanik und Thermodynamik*, Vol. 1, 1930, pages 34-41, 72-85, 113-120.

[2]Regeln für die Durchflussmessung mit genormten Düsen und Blenden, Verein deutscher Ingenieure, Berlin, 1930; 2nd edition, 1932.

[3]Fluid Meters, Their Selection and Installation, Part 3 of the Report of A.S.M.E. Special Research Committee on Fluid Meters, American Society of Mechanical Engineers, New York, 1933.

[4]Stach. Die Beiwerte von Normdüsen und Normblenden im Einlauf und Auslauf. *Zeitschrift des Vereines deutscher Ingenieure*, Vol. 78, 1934, pages 187-189.

[5]Kretzschmer & Wälzholz. Versuche über die Einbaufehler der Normblenden. *Forschung auf dem Gebiete des Ingenieurwesens*, Vol. 5, 1934, pages 25-35.

[6]Ruppel & Jordan. Die Durchflusszahlen von Normblenden mit und ohne Störung des Zuflusses. *Forschung auf dem Gebiete des Ingenieurwesens*, Vol. 2, 1931, pages 207-212.

[7]Witte. Die Strömung durch Düsen und Blenden. *Forschung auf dem Gebiete Ingenieurwesens*, Vol. 2, 1931, pages 245-251, 291-302.

FLOW MEASUREMENT

Discussion of F. J. Leerburger's Letter on Reynolds Numbers

(May issue, page 89)

To the Editor:

Congratulations to Mr. Leerburger for his discovery, but he apparently forgets Newton's Law: FORCE is the product of MASS and ACCELERATION. In Absolute System, MASS is in POUNDS and FORCE in POUNDALS. In Engineers' System, MASS is in SLUGS and FORCE in POUNDS (2nd Ed. Marks page 73). In any consistent system, DENSITY is MASS per UNIT VOLUME.

In Absolute System, VISCOSITY is expressed as POUNDAL-SECOND per SQ. FEET; but . . . from Newton: ONE POUNDAL is equal to ONE POUND-FEET per SECOND SQUARED; therefore, VISCOSITY may also be expressed as POUNDS per FEET-SECOND.

In Engineers' System, VISCOSITY is expressed as POUNDS-SECOND per SQ. FEET. This is the same numerically as SLUGS per FEET-SECOND (Blame Newton again).

If you try all the above on the piano, you will get a dimensionless sonata.

Independent Research Consultant
Ithaca, N. Y.

RAFAEL W. KEITH

To the Editor:

In the two examples given by Mr. Leerburger at the bottom of page 89 of the May 1934 issue of *Instruments*, consistent units have not been used. If one uses any homogeneous system of units there will be no discrepancy and the Reynolds' number always will be dimensionless. See the following examples, the first of which gives R using lb. force, the second gives R using lb. force converted to lb. mass, and the third gives R using lb. force converted to poundals. The reference used was Heat-Power Engineering by Barnard, Ellenwood and Hirshfeld, Part III, pages 791 and 796.

Conversion Factors

1 lb. force = 32.174 poundals
= (1 lb. mass) (32.174 ft. per sec.^{2})

$$1 \text{ lb. mass} = \frac{1 \text{ lb. force}}{32.174 \text{ ft. per sec.}^2}$$

1 slug = 32.174 lb. mass

2000 Second Ave.
Detroit, Michigan
May 25, 1934

H. E. BUMGARDNER

To the Editor:

Mr. Leerburger does not seem to have looked into the *definitions* of μ. They vary.

If the shearing force is given in pounds per square foot (see A. H. Gibson, *Hydraulics and Its Application*) then

$$\frac{F}{L^2} = \mu \frac{dv}{dy}$$

$$\text{or } \mu_1 = \frac{F}{L^2} \times \frac{L}{\frac{L}{T}} = \frac{M \times \frac{L}{T^2}}{L^2} \times \frac{L}{\frac{L}{T}} = \frac{M}{LT}$$

If the shearing force is given in poundals per square foot (see R. L. Daugherty, *Hydraulics*) then

$$\frac{P}{L^2} = \mu \frac{dv}{dy} = \frac{F \times a}{L^2}$$

$$\text{or } \mu_2 = \frac{F \times \frac{L}{T^2}}{L^2} \times \frac{L}{\frac{L}{T}} = \frac{\frac{\text{lbs.}}{g} \times \frac{L^2}{T^2}}{L^2} \times \frac{L}{\frac{L}{T}} = \frac{\text{lbs.}}{LT}$$

Hence in using Reynolds numbers care should be exercised, thus:

$$R_1 = \frac{Vd\rho_1}{\mu_1} = \frac{\frac{L}{T} \times L \times \frac{M}{L^3}}{\frac{M}{LT}} = 1$$

$$R_2 = \frac{Vd\rho_1}{\mu_2} = \frac{\frac{L}{T} \times L \times \frac{\text{lbs.}}{L^3}}{\frac{\text{lbs.}}{LT}} = 1$$

University of Pennsylvania
Philadelphia, Pa.
May 25, 1934

W. S. PARDOE

To the Editor:

Mr. Leerburger would be helpful if he would cite the particular American papers using Reynolds Numbers misleadingly. The writer has avoided confusion by using velocity V in feet per second, diameter D in feet and kinematic viscosity ν in square feet per second (or their c.g.s. equivalent—the only conversion factor being 1 foot = 30.48 cm.).

Providence, R. I.
May 29, 1934

ED S. SMITH, JR.

ABSOLUTE ENGLISH SYSTEM OF UNITS—FOOT, POUND FORCE, SECOND

$$R = \frac{(\text{ft.})\left(\frac{\text{ft.}}{\text{sec.}}\right)\left(\frac{\text{slugs}}{\text{cu. ft.}}\right)}{\frac{\text{lb. force sec.}}{\text{sq. ft.}}} = \frac{(\text{ft.})\left(\frac{\text{ft.}}{\text{sec.}}\right)\left(\frac{\text{lb. force}}{\frac{\text{ft. per sec.}^2}{\text{ft.}^3}}\right)}{\frac{\text{lb. force sec.}}{\text{ft.}^2}} = \frac{\left(\frac{\text{ft.}^2}{\text{sec.}}\right)\left(\frac{\text{lb. force}}{\text{ft.}^4 \text{ per sec.}^2}\right)}{\frac{\text{lb. force sec.}}{\text{ft.}^2}} = \frac{\frac{\text{lb. force}}{\text{ft.}^2 \text{ per sec.}}}{\frac{\text{lb. force}}{\text{ft.}^2 \text{ per sec.}}} = 1 \therefore \text{dimensionless}$$

$$R = \frac{(\text{ft.})\left(\frac{\text{ft.}}{\text{sec.}}\right)\left(\frac{\text{slugs}}{\text{cu. ft.}}\right)}{\frac{\text{lb. force sec.}}{\text{sq. ft.}}} = \frac{(\text{ft.})\left(\frac{\text{ft.}}{\text{sec.}}\right)\left(\frac{32.174 \text{ lb. mass}}{\text{ft.}^3}\right)}{\frac{32.174 \text{ lb. mass ft. per sec.}}{\text{ft.}^2}} = \frac{\left(\frac{\text{ft.}^2}{\text{sec.}}\right)\left(\frac{32.174 \text{ lb. mass}}{\text{ft.}^3}\right)}{\frac{32.174 \text{ lb. mass. ft. per sec.}}{\text{ft.}^2}} = \frac{\frac{32.174 \text{ lb. mass}}{\text{sec. ft.}}}{\frac{32.174 \text{ lb. mass}}{\text{sec. ft.}}} = 1 \therefore \text{dimensionless}$$

$$R = \frac{(\text{ft.})\left(\frac{\text{ft.}}{\text{sec.}}\right)\left(\frac{\text{slugs}}{\text{cu. ft.}}\right)}{\frac{\text{lb. force sec.}}{\text{sq. ft.}}} = \frac{(\text{ft.})\left(\frac{\text{ft.}}{\text{sec.}}\right)\left(\frac{32.174 \text{ poundals}}{\text{ft.}^4 \text{ per sec.}^2}\right)}{\frac{32.174 \text{ poundals sec.}}{\text{ft.}^2}} = \frac{\left(\frac{\text{ft.}^2}{\text{sec.}}\right)\left(\frac{32.174 \text{ poundals}}{\text{ft.}^4 \text{ per sec.}^2}\right)}{\frac{32.174 \text{ poundals sec.}}{\text{ft.}^2}} = \frac{\frac{32.174 \text{ poundals}}{\text{ft.}^2 \text{ per sec.}}}{\frac{32.174 \text{ poundals}}{\text{ft.}^2 \text{ per sec.}}} = 1 \therefore \text{dimensionless}$$

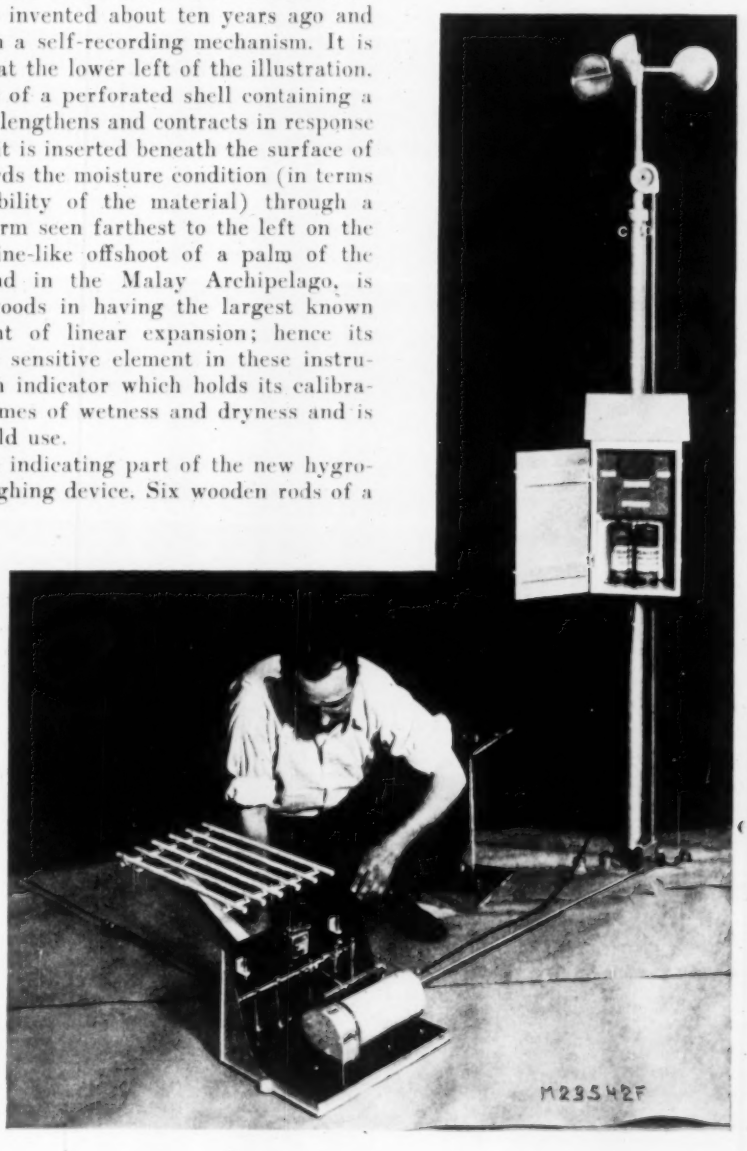
Forest Fire Hazard Recorder

Official Description Prepared for INSTRUMENTS by Forest Product Laboratory, U. S. Department of Agriculture

TO insure advance warning of forest fire dangers, the United States Forest Service has developed the "forest fuel hygrograph" shown in the illustration. It is a composite instrument which automatically indicates and records three important conditions that favor ignition and spread of a fire, namely, (1) dryness of the fallen leaf litter or duff, (2) dryness of slash or dead branch-wood on the forest floor, and (3) wind velocity.

The part of the new instrument that detects duff moisture is a hygrometer invented about ten years ago and now first embodied in a self-recording mechanism. It is the lance-like object at the lower left of the illustration. Consisting essentially of a perforated shell containing a strip of rattan which lengthens and contracts in response to moisture changes, it is inserted beneath the surface of typical duff and records the moisture condition (in terms of relative inflammability of the material) through a pulley and the pen arm seen farthest to the left on the drum. Rattan, the vine-like offshoot of a palm of the genus Calamus found in the Malay Archipelago, is remarkable among woods in having the largest known hygroscopic coefficient of linear expansion; hence its successful use as the sensitive element in these instruments. It provides an indicator which holds its calibration well under extremes of wetness and dryness and is rugged and fit for field use.

The wood-moisture indicating part of the new hygrograph is a direct weighing device. Six wooden rods of a species representative of the forest in which the instrument is to be used are mounted on a frame which is swung from fixed supports at one end. The other end, nearest the drum, is supported by a metal rod engaging a stirrup suspension which can transmit rotatory motion to the eccentrically weighted transverse shaft seen just inside the housing. By a spindle arrangement this rotation is converted to horizontal rotation of the second (middle) pen arm. The eccentric poises are adjusted to exact balance with the frame and the oven-dry weight of the wood rods when the pen is at one end of its arc, and with an additional weight equivalent to 80% moisture content in the rods when the pen is at its other limit. Any variations in weight of the rod system will be due solely to the amount of moisture absorbed or lost by the wood, and they will be recorded by the pen as the frame tilts slightly downward or upward. A dashpot is provided to prevent momentary disturbances of the weighing system by gusts of wind.



Wind movement is recorded by jogs of the third pen for every passage of ten miles of the air current as measured by the anemometer. Since the drum is driven at a steady rate by the instrument clock at the left of the drum, the length of each straight run of the pen between jogs is inversely proportional to the average miles-per-hour velocity of the wind, which therefore can be readily figured.

A feature of interest to *Instruments* readers who use recorders is that the clock and batteries mounted on the anemometer post actuate a vibrator (shown just above the recording pens) which is set off briefly at hourly intervals to neutralize possible sidewise drag on the pens on the paper and thus eliminate the possibility of pen-pressure error even if a user were to make a careless adjustment.

All framework and housing parts of the fuel hygrograph are of aluminum, and all suspensions (including those of the transverse weighing shaft) and pulley cords are of "foxtail" chain, insuring maximum strength and flexibility with minimum stretching. An aluminum hood, shown at the demonstrator's left, protects the recording mechanism from the weather, leaving the moisture-sensitive elements exposed.

Fire conditions on hundreds of millions of acres of American forests vary sharply from day to day and from week to week. By giving advance notice of fire danger, this instrument is potentially useful in the disposition and handling of large fire-fighting forces and mobile equipment on the national forests and elsewhere. It was designed by M. E. Dunlap of the United States Forest Products Laboratory, Madison, Wis., to meet needs suggested by H. T. Gisborne, of the federal forest experiment station at Missoula, Mont. One of the instruments was given successful service tests by Mr. Gisborne last year, and seven others have since been built in the Forest Products Laboratory shops by H. C. Hammes, machinist.

A New Method of Hardness Measurement

By A. L. De LEEUW

HARDNESS testing machines, commercially available at present, do not measure hardness. It is true that the results of hardness tests are given in figures, but these figures are arbitrarily chosen. It might have been better to express these results by letters of the alphabet, or other symbols which do not connote size or proportion. Numerals should not be used to indicate quantities or properties unless they are a true measure of them. It is proper to designate a one-inch bolt in the stockroom by "200" and a half-inch bolt by "300," for these numerals are then mere names, but it would not be correct to say that the diameter of the first bolt measures "200" and that of the second "300."

Apart from this misuse of numerals, existing hardness testing machines fail to give a quantitative expression of the relative hardness of two specimens. To say that the Brinell hardness of one piece is 400 and that of another 200 does not mean that the first piece is twice as hard as the second. In the Brinell machine the diameter of an impression made on the specimen by a small ball is measured under the microscope. There is no ascertainable relation between this diameter and the hardness, except that the harder the piece the smaller the impression. The trouble here is that the force required to make the impression is always the same, and that the effect is measured. In another machine the impression is made by a pointed diamond, and the depth of penetration is registered on a dial. Again there is no relation, expressible in numerals, between the indicator reading and the hardness of the specimen.

Controversial issues being involved in this article, *Instruments* hastens to proclaim its neutrality. Our opinion is that it's all a question of definitions: if any body of men proclaims that hardness is "the diameter of a ball's impression," "the angle of pendulum rebound," "the force to produce a given impression" or what not, it is just that—as far as that body of men is concerned!

The results of such tests are far from useless, as their widespread use indicates. If we find that a hardness "400" is suitable for a certain purpose, we can demand the same hardness every time we wish to get the same results. We can also test the specimens and make sure that we get what we specify.

However, this is not all that is required of a *measurement*. We could sell refractories in standard-make barrels of unknown content, but buyers desiring to know the value of various standard quantities would want to know the contents of these various barrels, because money is expressed in figures and quantities bought by money must likewise be expressible in figures.

In engineering practice the chief physical properties of metals, ultimate tensile strength, yield point, elongation, etc., are expressed in figures: in pounds and inches or percentages. Hardness is the only physical property not so dealt with —at least not in the most common practice. That it is desirable to do so should be self-evident. It would enable us to make hardness a factor in our calculations, as we now do with tensile strength. The machine described in this article is an attempt to obtain this result. Its construction lends itself to rapid manipulation and to the automatic making of permanent records. The basic principle of the machine is that an impression of *fixed* size is made and that the *force* required to make this impression is measured. Thus, when one specimen requires a pressure of 200 lbs. and another only 100 lbs., it follows that the hardness of the first piece is twice that of the second. The Shore Monotron also uses this basic principle. However, it requires careful observation, and does not make a permanent record. The machine which is the subject of this article makes a permanent record and it can be operated by unskilled labor.

In this machine* the piece of work is laid on a table on top of a hydraulic piston. This piston is moved upward by a pump driven by a small motor. As the piece moves upward it comes in contact with, and is indented by, a pointed diamond or a small hardened ball (for various conditions either the one or the other may be preferable). The diamond or ball (*P*, Fig. 1) is placed between two small hardened steel anvils (6, 6) the faces of which lie in a common plane (*f-f*). The diamond or ball projects slightly below this plane—say 0.005 in.—this distance representing, of course, the predetermined depth of impression. The anvils are electrically insulated (9, 9) and constitute portions of a low-voltage circuit. The moment the depth of impression is reached—*i.e.*, when the work touches the anvils—this low-voltage circuit is closed.

The amount of pressure required to make the impression varies with the hardness of the piece, and a pressure gage can be calibrated directly in hardness units. The machine includes a recording pressure gage: the same pressure of the oil actuates a piston in a smaller, but longer, cylinder. This piston acts against a calibrated spring and carries the terminals of a spark gap. A ruled paper strip chart between these terminals can be advanced either by hand or by mechanism every time a piece has been tested. Through a transformer the low-voltage current is made into a high voltage current, so that at the moment contact is made between the anvils and the work a spark jumps between the terminals of the spark gap and perforates the paper. The height of this puncture above the zero line of the chart is determined by the height to which the piston in the small cylinder has risen against the force of the calibrated spring and indicates therefore the amount of pressure which was required to make the diamond or ball penetrate to the proper depth. In this manner a permanent record is made of every test, and the automatic arrangement by which this is accomplished makes a 100 percent inspection possible in almost all cases.

It should be noted that the voltage used at the anvils is low, to prevent sparking between the anvils and the work, however small the distance before contact. On the other hand, the voltage of the high pressure circuit is sufficiently high to perforate chart paper. This spark method of making permanent records is only one of many possible ways: a pen might be used, or a stylus on waxed charts, etc., but spark records have the advantage of being tamper-proof.

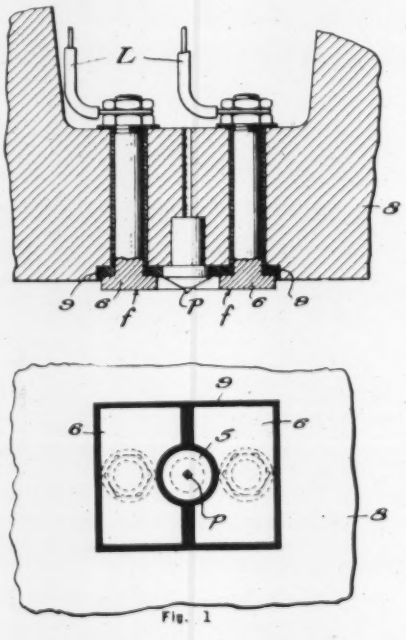


Fig. 1

The machine is provided with many automatic features. For instance, the table on which the work is laid is permitted a small amount of movement in any direction, so that irregularities in the work do not prevent its making contact with both anvils. At the moment when contact is made, current is also made to flow through a solenoid with retarded action. The retardation is only a small fraction of a second, yet the action of the solenoid is not instantaneous. Its action serves to stop the motor, and at the same time operate a valve reversing the flow of oil. Consequently, both large and small pistons return to the starting position. When a new piece of work is placed on the table, all that is needed to measure its hardness is to push a button which once more starts the motor on its next cycle.

The desirability of 100 percent inspec-

*U. S. Patent No. 1,768,512.

tion is generally recognized but it is not always practicable. Where one has to apply a microscope to measure an impression, such 100 percent inspection is out of the question, except for small lots: it certainly is not applicable to mass production. On the other hand, where only a few seconds are required for each piece and where no careful measurements have to be taken by a skilled or semi-skilled observer, such 100 percent inspection becomes feasible.

It may well be that for some kinds of work wide limits are permissible, but for other kinds the tolerances may have to be quite small. Present methods of testing hardness are not sufficiently sharp to permit of narrow tolerances (apart from the fact that 100 percent inspection is rarely possible) so that the limits, if they were set, would still indicate only that these pieces which have been tested are acceptable or otherwise.

There is at the present no positive method which makes it possible to say that the hardness of one piece in a lot is just right, that another piece is too low, that still another is too high. There is no definite line of demarcation. With the machine described above it is possible to draw such a line. It is possible, for instance, to specify that the hardness of a piece must be between 120 and 140 lbs., and that any piece which is below 120 or above 140 must be rejected.

It is obvious from the description that no skill or great care is required for making these tests, and this is an additional advantage. Another advantage, and perhaps an even greater one, is the fact that permanent records of all tests can be filed so that in the event of a complaint it would only be necessary to take the chart for the lot out of the file, and look up on it the particular test record of the individual piece.

NEWS AND NOTICES

The **Bausch & Lomb Optical Co.** plant, comprising sixteen buildings with over a million square feet of floor space, will be open to visitors to the Rochester Centennial during the week of Aug. 20 to 25. A schedule of trips under the direction of special guides is being arranged. One interesting division will be the instrument plant, covering about 271,000 square feet. In addition to daylight trips, arrangements are being made to open the astronomical observatory to out-of-town guests. Due to the limited capacity of the elevating floor of the observatory, guests are asked to register as far in advance as possible.

We have just had the honor of receiving from the hands of its Editor, Philip W. Swain, a copy of the 326-page Fiftieth Anniversary Issue of *Power*. The many articles, arranged under three sections ("Past," "Present" and "Future") include a 28-page "Story of Power" by E. J. Tangerman; ten 2-page general descriptions of notable plants by R. B. Purdy; thirteen pages of modern plant data compiled by F. A. Annett; a fascinating 7-page feature "Energy on Parade" by P. W. Swain; "Tomorrow" by Geo. A. Orrok; "Power from the Atom" by O. H. Caldwell, etc., etc.

The Fiftieth Anniversary Celebration of the Hebrew Technical Institute, New York, was held last May and *Instruments* is in receipt of a 76-page book commemorating this occasion. The Institute still remains the only American school conducting a course in Instrument Making. Admittance to the Institute is open without sectarian restrictions to youths "of fourteen years and upwards who are sincere in their desire for a technical education." Tuition is free. The Instrument Making Course is elective in the senior (third) year. The aim is to have graduates fit into industry and architecture as skilled artisans, draftsmen, etc.—not to prepare for universities or engineering colleges—but so thorough is the training that some graduates have, without further academic education, attained high positions in manufacturing industries, civil service, etc.

Lewis Air Conditioners, Inc., Minneapolis, have licensed Julien P. Friez and Sons, Inc., Baltimore, and Minneapolis-Honeywell Regulator Co., Minneapolis, under Patent No. 1,785,741, entitled, "Air Conditioning Systems." The Detroit Lubricator Co. had previously been licensed under this same patent, which contains broad claims relating to any air conditioning system or circuit wherein a humidity regulator is rendered operative by a thermally actuated regulator only when the heating medium has attained a temperature adequate for efficiently evaporating moisture and or otherwise conditioning the air.

INSTRUMENTS' BOOK SHELF

A.S.M.E. Power Test Codes. Series of 1934—Instruments and Apparatus—Part 6: Electrical Measurements. American Society of Mechanical Engineers, New York, 1934. Paper, 8 x 10½ inches. 57 pages. Price $1.25.

The Foreword states: " 'Instruments and Apparatus' is a discussion on instruments, quite apart from their specific applications in test code work. Details for the latter form a part of the particular test codes to which they apply." This part briefly introduces the various electrical units, defines standards, classifies instruments and gives a tabulation of limits of error. As it deals primarily with portable instruments and their connection for test purposes, no reference is made to switchboard apparatus or permanent installations. On the other hand considerable attention is given to the selection, transportation and general handling of test instruments. An important and much-neglected phase of test procedure, which here receives the attention it deserves, is the care that should be observed in making a temporary set-up, even considering proper illumination, as well as the bodily comfort and safety of the observer.

The principles of ammeters, voltmeters, wattmeters, power factor and frequency meters are illustrated by simple diagrams and concisely explained in a manner that leaves no room for conjecture; and frequent cross-references are made to a group of general paragraphs dealing with calibration, corrections and extraneous sources of error. Determination of power factor from wattmeter readings is discussed in considerable detail. Diagrams are shown for power measurement in the most common types of a.c. and d.c. systems; while a section of the work provides design data and instructions for building loading rheostats, both air and water-cooled.

Measurement of energy by the use of watthour meters is fully treated: the principal types of meters are described, and their adjustments and calibration explained. Instructions are given for resistance determination by the fall-of-potential method; but for bridge methods the reader is referred to another section of the Test Codes.

A summing up of the work is found in a section devoted to efficiency of electrical apparatus, with particular reference to the measurement of electrical output and input, as well as internal losses, together with methods of computing and applying these magnitudes in the determination of characteristic curves. A brief bibliography of references to standard works on electrical measurement concludes this part of the Code.

While the essentials of electrical measurements on dynamo-electric machinery may be said to be condensed in the half-hundred pages of this brochure, it does not purport to be a compendium of electrical instrumentation. It treats only those branches of the subject which, as a part of an over-all test on a power plant, might be expected to come within the jurisdiction of a mechanical engineer. Hence tests on transformers, transmission lines, regulators, etc. are not directly referred to, but are left to their logical sponsors, the electrical engineers. The data presented are strictly orthodox; "freak" methods of test have been assiduously avoided, so that the seasoned electrical instrumentician will often know of short cuts around some of the methods prescribed, yet there is little chance for erroneous practice on the part of the testing engineer who follows the procedures here presented. Beside a broad application in the field of plant testing, this Part of the Codes should have a particular appeal to teachers and students of practical electrical engineering subjects, both in the classroom and in their work on the test floor. —Perry A. Borden (4)-B-

The Design and Use of Instruments and Accurate Mechanism. By T. N. Whitehead. The Macmillan Co., New York, 1934. Cloth, 5¾x8¾ inches, 283+xiv pages. Price $3.50.

"Why is it that the United States, which leads in the volume of production of instruments, in the number of their practical varieties and forms, in the extent of their laboratory and plant utilization . . . lags behind Europe in the education of instrument designers and instrument-makers?" So asked *Instruments* editorially, in 1930, and went on to cite the courses by A. F. C. Pollard, Professor of Instrument Design at the Imperial College of Science and Technology, to describe America's only instrument-making course (one for boys), and to predict "magnificent triumphs" if the equivalent of Professor Pollard's advanced courses were given here, or at least if an industry-endowed research project at the Bureau of Standards were to bear fruit in the form of "frequent pamphlets utilizable as texts."

Since then a few excellent pamphlets related to instrument design, or dealing with specific principles thereof, have been issued in this country, but not one book on the general principles until now when, just as we were deploring this lacuna, there suddenly comes from the pen of an assistant professor at the Harvard School of Business Administration this book of nearly 300 pages devoted to the fundamental theory of design-for-accuracy, to practical examples thereof and to associated topics —this beautifully written text which at first glance should at once place America abreast of nations that had produced such works. But alas for our patriotic pride, Professor Whitehead seems to be a newcomer to this country; his book is largely a result of his experience as scientific officer to the British Admiralty; none but English and Swiss instruments are discussed as examples of correct design, and most of the few authorities cited are Englishmen.

This book, therefore, must be considered as one more British contribution to the science of instrument design—not as an American contribution. From an English point of view the words "and Use" in the title may be justified, but they make Americans expect a systematic discussion of uses, which the book does not contain. "Manipulation" would have been better, and

indeed the final chapter ("The Human Factor") treats this topic brilliantly in the form of what might be called a "sermonette" politely berating designers who ignore the factors of human judgment and physical action which "are continuously interacting when an instrument is in the hands of an observer." But even this final chapter was evidently written for the designer, and the author covers too big a territory in the first words of his preface: "The present book is written primarily for designers of instruments *and for those who use them . . .*" (italics ours). Nevertheless, although this book falls far short of being "required reading" for instrument users in general, it should make good reading for users of high-precision scientific instruments—particularly for users of delicate or "fussy" instruments which do not employ the valid principles expounded by Whitehead and by his predecessors (notably by Pollard in 1929 in his excellent little book on kinematic design). For all instrument designers, however, this new book is "required reading" *par excellence.*

In his preface the author points out that "the basic principles have been singularly stable for a very considerable time" and that "the time has come to take stock of the position" but he then proceeds to attack his precursors in a nearly page-long paragraph where he singles out "typical discussions of 'kinematic design'" as his pet hate just before asserting that "the present book represents a conscious revolt against mathematical abstraction when unaccompanied by an independent examination of the actual facts." Well and good, but when I first thumbed through this book I saw page after page of formulas, gained the impression of mathematical abstractions remote from the hard realities of design-for-accuracy, and remembered how I enjoyed my first reading of Pollard's little book which is packed full of practical suggestions without mathematical abstractions. Only once does Whitehead mention Pollard: as a second-choice reference in a bibliographical footnote!

This having been duly remarked, it is a pleasure to report that Whitehead's mathematical discussions occur mostly in his 131-page Part I on "The Theory of Errors" where they are relevant, and that his 135-page Part II on "Design" contains only 20-odd equations.

Between the preface and Part I there is interposed an introductory chapter entitled "Instruments and Their Parts" which alone entitles Whitehead to a niche in instrument-making's hall of fame by reason of his daring originality—amounting to nothing less than a new philosophy of instrument design and construction. It of course requires a new terminology and therefore cannot be summarized here without risk of conveying a distorted picture, but his central idea is that all of the various errors to which an instrument is liable can be classified as follows.

Fault in Element	*Resulting Error*
1. False element	Systematic error
2. Disturbed element	Short period error
3. Incomplete element	Erratic error

Bear in mind that this remarkable first chapter is almost wholly devoted to defining "element," "error," "false," "disturbed," "incomplete," "systematic," "short period" and "erratic," and that these definitions reveal a brilliant, vigorous, unfettered mind; and you will not wonder why I understood as soon as I had finished reading this chapter, that the author felt justified to include in his preface some passages which would ordinarily provoke the wrath of technical magazines. "Tout comprendre, c'est tout pardonner!"

Part I discusses "false," "disturbed" and "incomplete" elements and the specific classes of errors to which they give rise; and contains also a chapter on "Probability as Applied to Errors" in which Whitehead mercilessly assails some other writers on this subject (but by this time the reader has learned to enjoy these polemics) and a final chapter in which the author discusses a series of measurements he made some years ago to determine the accuracy with which a particular telescope could be set on a collimated line, and leads up to a novel discussion of "mental restoring agencies."

Part II deals in a practical manner with Design. It is logically divided into six brief chapters: "Precision—Kinematic Design," "Precision—Semikinematic Design," "Stiffness, Isolation and Protection of Elements," "Accuracy," "The Planning of an Instrument" and "The Human Factor." This last chapter, too, would entitle Whitehead to lasting fame, but then, so would the ten intervening chapters—if they were accompanied by a glossary abstracted from Chapter I!

"No one has ever experienced a partial error." "Never measure more than absolutely necessary." "A man stamping his foot in Hong Kong shakes a laboratory in Europe." "Precision is the quality of constancy as applied to the elements of an observation."—Yes, the author certainly knows how to write; but impetuousness mars his style: he uses the word "very" at least 150 times—at least 140 times superfluously—and once a page on the average he lapses into vagueness when using qualitative expressions such as "a little."

This book will undoubtedly make a stir throughout the American instrument industry. Whitehead will be ridiculed by some old-timers, for his book *is* rather provocative in spots, but this reviewer—who nearly thirty years ago designed instruments on the board and built them on the bench—does not hesitate to offer his trusty old sword (a portable typewriter) to the promising son of the illustrious Professor A. N. Whitehead.

M. F. BÉHAR (12)-B-

Temperature Regulators (Temperatur Regler) By RUDOLF STOHN. Carl Marhold Verlagsbuchhandlung, Halle, Germany, 1933. Cloth, 6x9 inches, 181 pages. Price 7 RM.

When the first two assertions in the preface of a book are untrue, the whole book may be suspected of being meretricious. Rudolf Stohn starts by declaring that (1) "in all German technical literature there is no work which even to the least extent discusses temperature control," and (2) "even in technical journals only a few short articles have appeared."

So much for the beginning. The back of the book is an advertising section. There are thirty firms in it.

There are thirty firms whose products are extensively described in the body of the book.

The two lists coincide.

The text is mostly made up of the thirty manufacturers' sales literature, describing room thermostats with a sprinkling of industrial models. Maybe that is why the preface is signed Der Verfasser (The Editor) and not "the author." But Stohn seems to have done some writing of his own, especially in the 17-page Part A on Temperature Regulat*ion* (Part B, the 153-page main text, dealing with Temperature Regulat*ors.*) Part A consists of a 14-page chapter on Temperature Regulation and Room Heating and a 3-page chapter on Temperature Regulation in Industry. These two chapters must be read to be appreciated, so here is a sample, consisting of Fig. 1 and Stohn's explanation thereof:

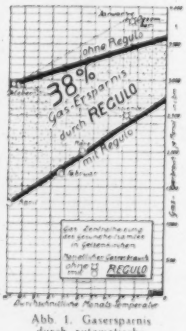


Abb. 1. Gasersparnis durch automatische Temperaturreglung.

Das Diagramm Abb. 1 läßt die Ersparnis-Möglichkeiten erkennen, die auch in Gasfeuerstätten durch zweckmäßige automatische Temperaturreglung erzielt werden können. Bei diesem Heizmittel muß besonders nach jeder Ersparnismöglichkeit gegriffen werden, wenn im Konkurrenzkampfe mit der Kohlefeuerung ein einigermaßen tragbares Verhältnis geschaffen werden soll. Die Gasraumheizung, gleichgültig ob zentrale oder Einzelheizung in Frage kommt, ist kein Luxus mehr — wenn man sie durch Temperaturregler wirtschaftlich gestaltet!

In neuerer Zeit ist der Gaspreis fast allgemein für Raumheizung auf 10 Pf./m³ herabgesetzt worden. Für 1 kg Steinkohle mit 7500 WE ist etwa 4 Pf. anzusetzen. Die Gaswerke liefern ein Gas von 4000 WE/m³ im Mittel. Stellen wir die reinen Heizwerte der beiden Brennstoffe Gas

Some 100 regulators are described in Part B—mostly by their own makers, but it must be said that their arrangement in nine chapters and numerous sections is an excellent job—a time-saving convenience to the user. All of the American devices shown are familiar; most of the German devices work on familiar principles, but two or three of them differ from anything we have on this side—not enough, however, for an American instrument firm's development engineer to get excited. One searches these chapters in vain for mention of certain systems (German or American) which engineers think well of. Their makers are not among the advertisers in the back of the volume.

M. F. BÉHAR (2.00)-B-

Calibration and Standardization of Chemical Glassware (Eichung und Normung Chemischer Glasgeräte) By FRITZ FRIEDRICHS. Verlag "Glas und Apparat," Weimar, 1933. Paper, 9¼ x 12½ inches, 24 pages. This pamphlet is based upon a series of articles which appeared in the periodical *Glas und Apparat.* It is divided into chapters: 1. Volumetric Flasks, 2. Graduates and Measuring Cylinders, 3. Transfer Pipettes, 4. Burettes, 5. Measuring Pipettes, 6. Gas Burettes, 7. Nitrometers, 8. Azotometers, 9. Pycnometers, and 10. Hydrometers. Each chapter discusses calibration and standardization with the consideration for the economic production of a complete unit.

RICHARD RIMBACH (11)-B-

The Inventor and His World. By H. STAFFORD HATFIELD. E. P. Dutton & Co., New York, 1933. Cloth, 4½x7¼ inches, 254 pages. Price $2.40.

That there is still a great field for the individual inventor, in spite of the great research laboratories and their highly trained scientific personnel, is the main contention; the author backs it up with numerous specific subjects for inventing presented in the chapters on "Chemical Invention," "Electrical Invention," "Psychological Inventions," and "Invention and the Transformation of Energy." These suggestions are so presented as to encourage the individual inventor to creative effort in these fields.

Noisy fanfare over the great research laboratories of huge industrial concerns has created the impression that industrial progress has become a matter of "systematic development" carried on in great laboratories by scientists of specialized training, working in large, highly organized groups; and that the day of the individual, groping inventor, working independently, is passing.

This erroneous impression has done great harm, for it has undoubtedly frightened a good deal of inventive talent from creative activity. Therefore, in so far as it combats this impression, and does it well, this book is to be commended.

Interesting, valuable and novel is the author's innovation of suggesting biology as a field for invention. A whole chapter on "Biological Invention" points out that this is an as yet almost untouched field for invention, and presents many specific subjects in that field suitable for the individual inventor to work on.

Interesting and valuable, too, is the author's explanation, presented for the first time in a "handbook addressed to inventors," that the patent law is basically faulty, in that a patent is not a legal guarantee of property but merely an invitation to litigation. This, and some suggestions as to what should be done about it, are presented in the chapter on Patent Law.

For the rest, the book is worthless. In the first three chapters, "What is Invention?" "The Inventor" and "The Practice of Invention," Mr. Hatfield has produced a morass of jumbled speculation drowned in a sea of words. The speculation is apparently a hang-over from a French book on "Invention and the Unconscious," which Mr. Hatfield translated. The chapter on "Working Out and Financing an Invention" is inferior to the treatments of that subject to be found in many books on patents.

Altogether, the book is of value in those parts which are inspiring to the individual inventor. The rest of the book is not worth while.

H. OLKEN (12)-B-

Electrons At Work. By CHARLES R. UNDERHILL. McGraw-Hill Book Co., Inc., New York, 1933. Cloth, 6x9 inches, 312 pages, 220 figures. Price $3.00.

The author has unquestionably fulfilled the requirements for a book telling "why and how electrons are at work" in a simple style readily digestible by the average reader. Several books dealing with kindred topics are available, it is true, but none treats the entire subject matter so concisely. The author first defines under "Introductory" the nature and properties of

(Continued on Page 151)

Determinations of Phase Angle*

By PERRY A. BORDEN† and M. F. BEHAR**

1. Significance of Phase-angle.

The current in an alternating-current system may or may not pass through its successive cyclic values at the same instants as the corresponding values are reached by the voltage. When the two magnitudes are in time-phase agreement, the total power in the circuit is represented by the product of their effective values. When they are not in such agreement their product is only the "apparent power" or *volt-amperes* of the load—a magnitude to which must be applied a multiplying factor in order to arrive at the true value of the power flowing. This factor is known as the *power factor* of the load. Its value may vary between +1 and —1, but is generally expressed in percent. When the current reaches its respective values later in the cycle than the voltage, the power factor is said to be *lagging*, and when earlier, *leading*. A detailed discussion of power factor values, as affected by various relative time-phase positions of current and voltage, appeared in the February article on General Principles. As long as current and voltage can be considered as following a sine-wave law, the term *power factor* can be given a trigonometrical interpretation, and expressed as the cosine of the phase-angle between the current and the voltage. Practically

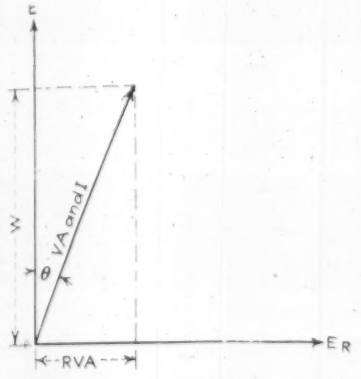


Fig. 35-1. Vectors Considered in Power Factor Determination.

E – Line voltage
E_r – Quadrature voltage
VA & I – Volt-amperes and current
W – Active component of volt-amperes
RVA – Reactive component of volt-amperes
θ – Phase angle between current and voltage

$$\text{Power factor} = \cos\theta = W/VA$$

$$\text{Reactive factor} = \sin\theta = RVA/VA$$

$$\text{Tan}\ \theta = \frac{\sin\theta}{\cos\theta} = \frac{RVA}{W}$$

$$VA = \sqrt{W^2 + (RVA)^2}$$

all instruments and methods for determining power factor interpret the definition in this sense. In Fig. 35-1 is shown a vector diagram to illustrate the relations existing among the magnitudes involved in power factor considerations, the principal of which are:

Apparent power: product of volts and amperes; expressed as *volt-amperes*.

Actual power: working, or in-phase, component of the volt-amperes, expressed as *watts*.

Reactive component: idle or quadrature component of the volt-amperes, expressed as *reactive volt-amperes*.

A discussion of the economic significance of power factor is not within the scope of this work. Suffice it to say that the power factor at which a load is supplied has an important bearing upon the cost of supplying the power, and also upon the efficiency with which power lines and electrical equipment are utilized, so that it is to the advantage of both the supplier and the user of electrical energy to have a knowledge of this magnitude, with the general object of maintaining its value as near to unity as is possible. The actual determination of power factor as an intrinsic magnitude is perhaps not attended with the same degree of importance as it was a few years ago. This is because there have recently been evolved a number of ingenious methods of establishing the costs upon which to base power charges, which methods, while having to do with power factor, do not require its direct measurement. In tests, and in the actual operation of electrical plants and machinery, however, a knowledge of the power factor of the load is still an important consideration.

*Seventh chapter (XXXV) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Bĕhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook will be published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

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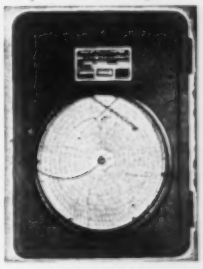

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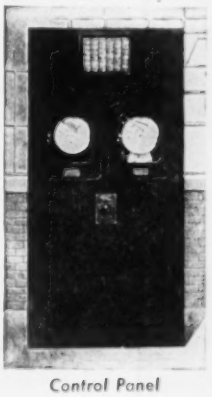

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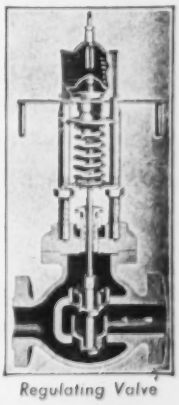

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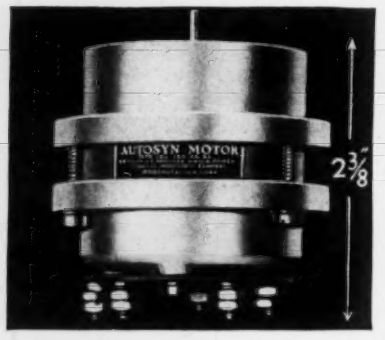

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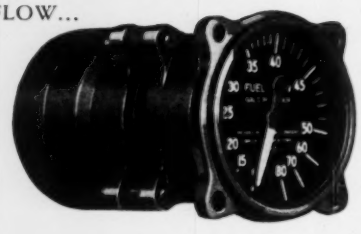

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2. Direct determination of power factor.

The general principle of the power factor indicator was outlined in the March article on Measuring Elements. An elementary diagram of a single-phase power factor measuring element is shown in Fig. 35-2. The stationary field coil carries the line current, while the crossed-coil moving element is connected to the line through a resistance and a reactance, so that a rotating field is produced by its windings. The moving element then tends to place itself in a position where the alternating field of the current coil is in phase with the resultant of the currents in the moving coils. If the phase position of the line

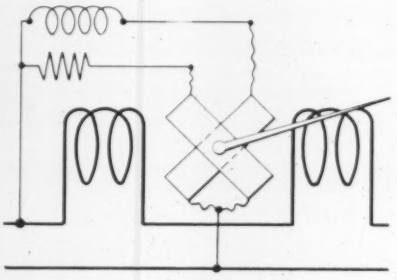


Fig. 35-2. Crossed-coil power factor indicator—single phase.

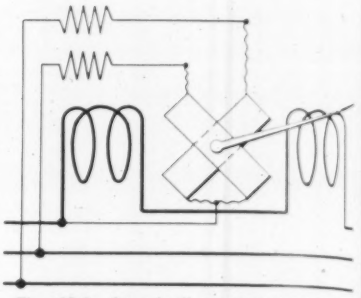


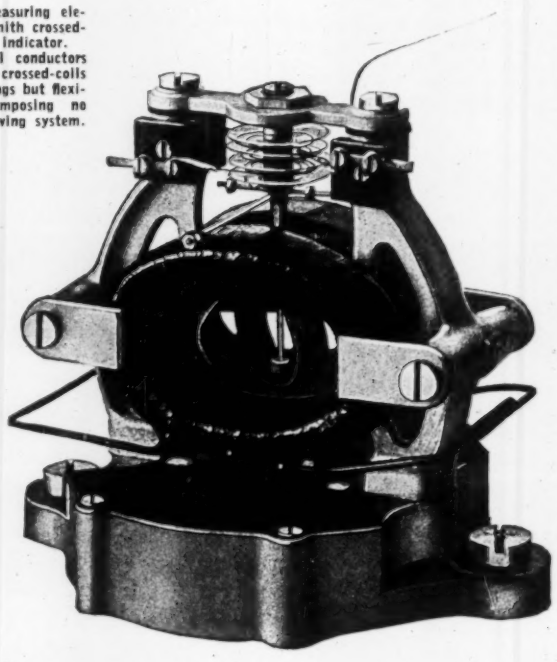
Fig. 35-3. Crossed-coil power factor indicator—polyphase.

current varies in relation to the exciting voltage of the potential element, that of the field also will vary, and the moving element will reposition itself. Thus the position of the moving element represents the phase-position of the current relative to the voltage, and the scale may be calibrated in terms of power factor.

The connection of a power factor indicator to the circuit under measurement is similar to that of a wattmeter, in that both the voltage and current of the system must produce an effect in the measuring element. In instruments for

Fig. 35-4. Measuring element of Roller-Smith crossed-coil power factor indicator.

The four spiral conductors at the top of the crossed-coils staff are not springs but flexible ligaments imposing no torque on the moving system.



single-phase systems the rotating field is produced as outlined above, by "artificially" effecting a phase-shift between the currents in the displaced windings of the crossed-coil movement. As the phase displacement of these currents would ordinarily vary with the frequency of the voltage, single-phase power factors are calibrated at the frequency for which they are designed. It is possible to obtain portable power factor indicators calibrated for two distinct commercial frequencies (*i.e.*, 25 and 60 cycles) in one instrument. Where it is known that a polyphase source of voltage will be obtainable, as in most switchboard installations, there is employed a form of instrument in which the crossed coils are energized from two phases of the system through series resis

tors, as in Fig. 35-3. Such instruments may generally be used on any frequency within the industrial range (*i.e.*, up to 60 cycles) without readjustment. It is to be observed that while instruments of this class are intended for use on polyphase circuits, the indication on the scale represents the power factor corresponding to the current in the particular conductor which passes through the field coil, and not necessarily the power factor of the polyphase load. This point is further discussed in a subsequent article on "Considerations of Unbalanced Loads." The measuring element of a modern type of power factor indicator (Roller-Smith) is shown in Fig. 35-4, and this may be considered as typical of present-day practice.

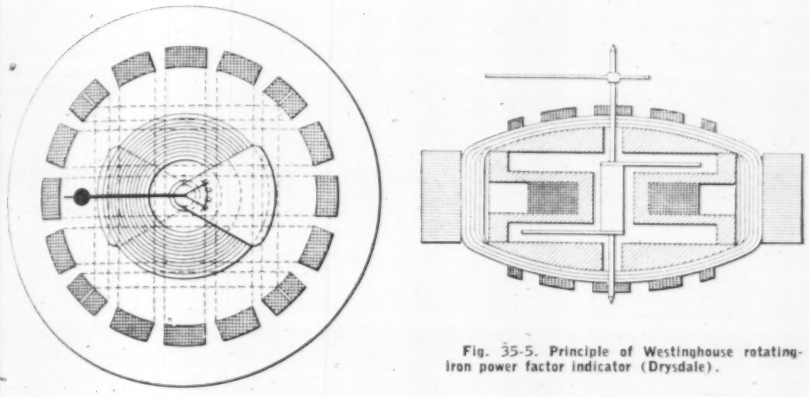


Fig. 35-5. Principle of Westinghouse rotating-iron power factor indicator (Drysdale).

An early form of Westinghouse power factor indicator, shown in section in Fig. 35-5, has its rotating field produced by an interwoven structure of angularly placed coils enclosing a ⊥-shaped iron vane carried on the shaft of the instrument, and magnetized by a stationary current coil concentric with its axis. This vane will assume a definite position corresponding to the phase relationship between voltage and current at any point in the whole 360 degrees of the cycle. For single-phase applications the coils are excited through a phase-splitting circuit as in Fig. 35-2, while for polyphase use the several coils are connected through suitable resistances to the respective line conductors, as in Fig. 35-3. In some early forms of this power factor indicator the functions of the current and voltage coils were interchanged, the iron vane being magnetized

Fig. 35-6. Westinghouse phase indicator, calibrated in electrical degrees.

Fig. 35-7. Conventional power factor indicator scale (Westinghouse).

by a single voltage coil, and the enclosing system being made up of a polyphase winding carrying the line currents. A modern form of this instrument, known as a *phase indicator*, and having its scale calibrated in geometrical degrees, is shown in Fig. 35-6.

In many of the earlier power factor indicators, like the Westinghouse instrument mentioned above, the scale was made geometrically equivalent to the circuit, so that the pointer might be looked upon as a vector representative of the phase position of the line current. Even the instruments with moving coils, requiring the use of leading-in filaments or "ligaments," have been made with scales of as much as 300 geometrical degrees. For central stations and interconnecting points of a system this practice has much to recommend it; and such instruments are available where required. The general tendency at present,

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however, is to provide an instrument having a scale of about 90 geometrical degrees, and include thereon the desired range of power factors by conformation and adjustment of the parts of the instrument. Fig. 35-7 shows the scale of a power factor indicator of this type.

Under some operating schemes the measurement of *reactive factor* (see Fig. 35-1), rather than *power factor*, is required. In its construction, connection and adjustment the reactive factor indicator is identical with the power factor indicator; but the scale, instead of being calibrated in terms of the cosine of the phase-angle, is expressed in terms of the *sine* of that angle. Of course it is possible to have both these magnitudes marked on a common scale, so that readings may be expressed in terms of either of the units involved.

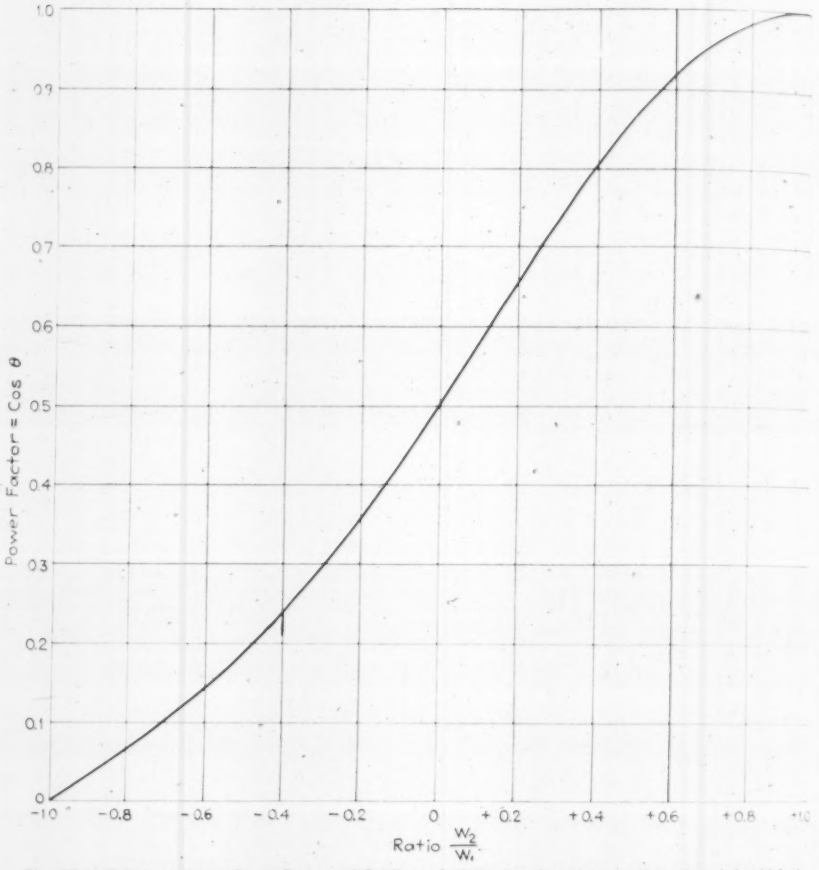

Fig. 35-8. Relation between Power Factor and Readings of Wattmeter elements on a three-phase balanced load. W_1 = greater reading. W_2 = lesser reading.

3. Power factor from Wattmeter Readings.

The power factor of a balanced polyphase load may readily be obtained from readings taken on a two-element wattmeter connected in the circuit. On a two-phase system, where the voltages are normally 90 degrees out of phase, transposing the voltage connections of the two metering elements gives an indication of the reactive volt-amperes; and the ratio of this magnitude to the active volt-amperes (or watts) represents the tangent of the phase angle—the angle whose cosine is the power factor of the load. On a three-phase system, the computation is based on the readings of the two elements of the wattmeter. By disconnecting the voltage leads one at a time the two elements may be read separately. Designating the greater of these readings W_1 and the lesser W_2, the tangent of the phase angle may be found by application of the formula:

$$\text{Tan } \theta = \sqrt{3}\ \frac{W_1 - W_2}{W_1 + W_2}$$

The power factor of the circuit—the cosine of the phase angle, whose tangent is derived above—may be determined by reference to the second and third columns of Table 35-I or to trigonometric tables to be found in any engineering handbook. The first and third columns of the accompanying tabulations are expressed graphically in Fig. 35-8, so that power factor values may be read directly from the ratio W_2/W_1 without mathematical computation.

TABLE 35-I—POWER FACTOR DETERMINATION

Relationships between wattmeter readings and functions of the phase angle of a three-phase balanced load

Ratio $\frac{W_2}{W_1}$	Tan θ	Cos θ (Power factor)	Ratio $\frac{W_2}{W_1}$	Tan θ	Cos θ (Power factor)
—1.0	∞	0	0.0	1.73	0.500
—0.9	34.36	0.030	0.1	1.40	0.580
—0.8	15.60	0.064	0.2	1.15	0.655
—0.7	10.00	0.101	0.3	0.93	0.732
—0.6	7.00	0.143	0.4	0.74	0.803
—0.5	5.15	0.189	0.5	0.57	0.867
—0.4	4.04	0.240	0.6	0.53	0.918
—0.3	3.20	0.298	0.7	0.30	0.958
—0.2	2.60	0.359	0.8	0.19	0.982
—0.1	2.11	0.428	0.9	0.13	0.991
0.0	1.73	0.500	1.0	0	1.000

Note: The two-wattmeter method of determining power factor is suited only to a balanced load, and one which is sufficiently steady that no material change takes place during the time of observation. In the case of negative readings, as will be obtained for W_2 when the power factor of the load is below 50%, either a reversing switch may be used in the potential circuit of the wattmeter, or W_1 and W_2 may be taken simultaneously. The total reading of the load is $W_1 + W_2$, so that $W_2 = (W_1 + W_2) - W_1$. Where a negative sign is associated with any reading it must be retained in any algebraic computation.

The above method is applicable to watthour meters by comparing disk speeds under the different connection arrangements. When the speed of rotation is very slow the ratio may be determined by observing the ratio of the time-intervals required for one revolution of the disk. For since the speed of the disk is inversely proportional to the time of rotation, it follows (if T_1 and T_2 designate the respective times of rotation of the disk) that $W_2/W_1 = T_1/T_2$.

4. Determination of Reactive Component.

As the actual useful power in a circuit is based upon the *active* component of the current in the circuit—that is, the component which is in phase with the voltage (See Fig. 35-1), so the *reactive* component is looked upon as the component which is in quadrature with the voltage, and therefore represents no useful work. If the value of the power be represented by the product of volts × amperes × *cosine* of the phase angle ($EI \cos \theta$), so the value of the reactive component is represented by the product of volts × amperes × *sine* of the phase angle ($EI \sin \theta$). In general the reactive component is for the most part made up of magnetizing current, or that element of the current which is necessary to maintain proper magnetic conditions in the cores of alternating-current apparatus of an inductive nature. It is an essential property of alternating-current circuits that magnetizing current—that element of the current whose magnitude is limited by the inductive property of the circuit—always lags the voltage by a time-phase angle of 90 electrical degrees. Capacitance in a circuit, such as that introduced by a long transmission line, on the other hand, permits the flow of a current leading the voltage by 90 electrical degrees. The effect of capacitance, therefore, is to neutralize that of inductance; so that it has become a common practice to introduce capacitance or its equivalent into a system, for the sole purpose of balancing out the effect of the unavoidable magnetizing current, and thus maintaining the power factor as near as possible to its unity value. In the light of these considerations the definition of power factor is the cosine of that angle whose tangent is equal to the ratio of the reactive to the active component of the load current; and as will be seen later, probably the most satisfactory determinations of power factor in polyphase work are based upon this definition.

The principle of measurement of reactive component is simple: it consists in furnishing to the potential circuits of a wattmeter whose current coils are connected in the ordinary manner, voltages differing in phase position by 90 electrical degrees from the voltages normally applied to these coils. This system is equally applicable to single-phase circuits and to any polyphase circuits upon which measurements may be made with a wattmeter; and, so long as the voltage and current follow a sinusoidal law, the value obtained may be considered as that of the reactive component. With non-sinusoidal current or voltage in the circuit, while the wattmeter continues to give the true average power, the instrument having its potential coils excited from a voltage in quadrature with the line voltage gives a reading which must be arbitrarily defined as the reactive component. Taking this value, however, it may be combined satisfactorily

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MANUFACTURERS' NEW LITERATURE

In this department we each month list the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

B191 **Better Electric Welding at Less Cost.** Bulletin No. 334 of The Graphic covers the use of recorders to study the welding operation. Esterline-Angus Co., Indianapolis, Ind.

B192 **Beater Roll Recorder.** Leaflet P-20 describes this instrument for keeping an accurate record of beater roll settings. Thwing Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.

B193 **Udylite News.** The April 1934 issue of this house organ contains the following: The Guthfan Conditionair; and Selecting the Proper Plated Coating. Udylite Process Co., 3939 Bellevue Ave., Detroit, Mich.

B194 **Substation Equipment.** Catalogue 4037 describes the new developments in substation equipment. American Automatic Electric Sales Company, 1033 W. Van Buren St., Chicago, Ill.

B195 **Miniature Steam Generators.** Bulletin No. 52A gives data on electric-heated miniature steam generators. Commonwealth Electric & Manufacturing Co., 83 Boston St., Boston, Mass.

B196 **Electric Heating Elements.** Leaflet TB30 gives data on various electric heating units. Harold E. Trent Co., 618 N. 54th St., Philadelphia, Pa.

B197 **Colloidal-Graphited Lubricants.** Technical Bulletin No. M182 is entitled "Concerning the Use of Colloidal-Graphited Lubricants in Ball Bearings." Acheson Colloids Corp., Port Huron, Mich.

B198 **Boiler Meters.** Engineers will be interested in the new 32-page bulletin "Savings Effected by Bailey Boiler Meters," just issued. This bulletin includes operating data showing the nature and amount of savings effected in over 20 installations. Bailey Meter Co., 1050 Ivanhoe Road, Cleveland, Ohio.

B199 **Combustion Indicators and Controls.** Bulletin 3A1 illustrates and describes "Electric Eye" combustion indicators and controls. Ess Instrument Company, 816 Agnes Street, Parkersburg, W. Va.

B200 **Binoculars.** Small leaflet on binoculars. Bausch & Lomb Optical Co., Rochester, N. Y.

B201 **General Radio Experimenter.** The April 1934 issue contains the following articles: General Radio-Hazeltine Reactance Meter; Shielded Transformer for Bridge-Circuit Use. General Radio Company, 30 State Street, Cambridge A, Mass.

B202 **Grits and Grinds.** The March-April issue contains the following: Norton Controlled Structure Wheels Meet All Cylindrical Grinding Job Requirements; and Steel Chips Generated by Metalite Discs. Norton Co., Worcester, Mass.

B203 **"Cost Saving Instrumentation for the Chemical Industries."** This leaflet lists the various quantities which can be measured with the instruments manufactured by Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

B204 **Die Casting Advances Increase Applications.** This article, reprinted from Machine Design attempts to explain some of the advances made in die castings during 1933. New Jersey Zinc Co., 160 Front St., New York City.

B205 **Gas Burette.** 12-page bulletin entitled "Original Morehead Gas Burette for the Analysis of Industrial Gases" gives a description of the burette and directions for its use. E. H. Sargent & Co., 155 E. Superior Street, Chicago, Ill.

B206 **Galvatron.** Bulletin No. 140 bearing this title gives information on the new Bailey potentiometer recorder for temperature, smoke density and telemetering. Bailey Meter Co., 1050 Ivanhoe Road, Cleveland, Ohio.

B207 **Precision with Simplicity.** Small leaflet on the type FS microscopes. Bausch & Lomb Optical Co., Rochester, N. Y.

B208 **Bakelite Review.** The April issue of the Bakelite Review illustrates several applications of Bakelite to instruments. Bakelite Corp., Bound Brook, N. J.

B209 **Laboratory Electric Heater.** Bulletin 1521 lists the following: New Electric Heater for Laboratory Use; Heavy Duty Rheostat and a Miniature Steam Generator. American Instrument Co., 774 Girard Ave., Washington, D. C.

B210 **Projection Apparatus.** Catalog No. 577 distributed by The R. Y. Ferner Co., 930 Investment Bldg., Washington, D. C., American agents of the Societe Genevoise d'Instruments de Physique, describes a desk-type projection apparatus for the easy inspection, measurement and photography of small manufactured articles and various types of materials including textiles. Of special interest is an attachment for Episcopic Illumination of the face of articles and samples placed on the horizontal object table, to permit measurement and examination of the surface of materials.

B211 **Gas Calorimeter.** 4-page bulletin describes portable instrument permitting simultaneous tests of unknown and of standard, obviating corrections. The Hays Corp., Michigan City, Ind.

B212 **Electrical Tests.** Bulletin 1375 describes portable and entirely self-contained "Megger Capacity Meter." Bulletin 1380 describes new line of "Midget Megger" circuit testing ohmmeters. James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

B213 **Portable Gas Analyzer.** Bulletin 20 describes the new portable gas analyzer. Ellison Draft Gage Co., 214 West Kinzie St., Chicago, Ill.

B214 **Groundometers.** Bulletin No. 130 discusses the measuring of resistance with earth electrodes. Application is discussed. Borden Electric Company, Summit, N. J.

B215 **Temperature Regulator.** Leaflet gives the features of a new temperature regulator. Emil T. Johnson Co., 645 N. Talman Ave., Chicago, Ill.

with the actual power in any geometrical formula. Conditions existing with unbalanced loads are treated in a subsequent chapter.

On three-phase metering circuits, quadrature voltages for reactive component measurement may be obtained from special transformer connections, as shown in Fig. 35-9. This arrangement is suited for use with any type of wattmeter element, whether inductive or non-inductive. For wattmeters of the electrodynamic type having substantially non-inductive potential circuits, quadrature voltages may be derived from an arrangement of series resistors as shown in Fig. 35-10. Of the two systems, the transformer arrangement is probably the more desirable because of the tendency to suppress harmonics which may exist in the voltage wave. It is common practice to install a wattmeter and a reactive component indicator together, so that the two related magnitudes may be simultaneously determined. On some large power systems the latter instrument is provided with a throw-over switch, as in Fig. 35-10, so that, in event of the wattmeter in the circuit being out of service, the reactive component indicator may be used as a wattmeter, thus sacrificing what is generally the less important of the two readings. This throw-over switch also facilitates calibration of

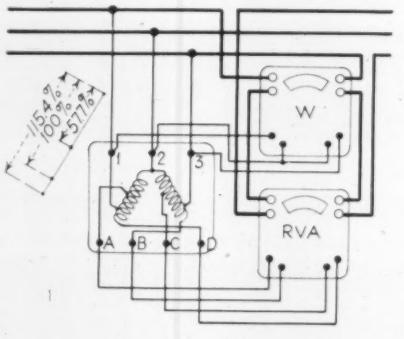


Fig. 35-9. Direct measurement of reactive volt-amperes with wattmeter and phase-shifting transformer. (R.V.A. Compensator) Wattmeter and reactive volt-ampere meter on same load.

This arrangement is suitable for either electrodynamic instruments or induction-type meters.

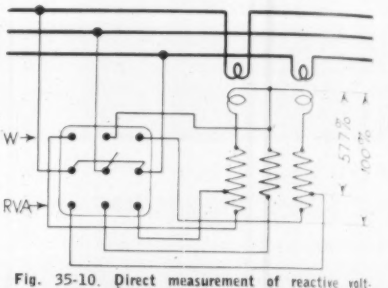


Fig. 35-10. Direct measurement of reactive volt-amperes with modified series resistors. Total resistance of each voltage element of wattmeter must be brought to a common value R, calibration and balance between elements being effected mechanically. Taps are brought out at 57.7 R points on series resistors, and a third unit of resistance value = 57.7 R added. Throwing the switch in the diagram to the UP position causes the instrument to read watts, and the DOWN position reactive component. This method suited only to use with instruments having a high ratio of resistance to inductance in the potential circuits.

the instruments in their permanent location. On three-phase systems where the neutral point is accessible, quadrature voltages may be obtained by taking potentials to neutral and transposing the connections to the two elements of the wattmeter. Thus each element will have applied to it a voltage 90 degrees out of phase with its normal voltages; but since these quadrature voltages will be only 57.7% of the normal voltage in magnitude, it becomes necessary either to divide the reading by 0.57 or else to provide tapped series resistors to compensate for the changed value. On two-phase circuits, since the phase voltages are normally 90 degrees apart, reactive component measurement only requires that the two wattmeter elements have their voltage connections interchanged.

In the conversion of a wattmeter into a reactive component indicator by applying 90° phase shift to the potentials, due account must be taken of the phase rotation of the system. With a lagging power factor to the load the voltages should be shifted 90° in the lag direction and with a leading power factor, an equal amount in the lead direction. A simple check on phase rotation may be made as follows: With the instrument connected as shown in either Figs. 35-9 and 35-10, a unity power factor condition should give a zero reading. As the power factor departs from unity the reading of the instrument should increase. If the instrument reads reversed the phase rotation is incorrect and should be rectified. This may be accomplished by interchanging the voltage leads which connect to the lines in which current is measured (which reverses the phase rotation of the potential system); and interchanging the current transformers in their relation to the current coils of the instrument: i.e., supplying the left hand element from that transformer which formerly supplied the right hand element and vice versa (which reverses the phase rotation of the current system). This change if properly made should have no effect on the reading of the instrument as a wattmeter.

5. Volt-ampere Determination.

The direct determination of the magnitude known as *volt-amperes* in any but a single-phase circuit is more difficult than that of either active or reactive component. In a single-phase circuit, measurements of the voltage and of the current, multiplied by each other, give directly the true value of volt-amperes; but on polyphase systems the currents in the several conductors must be multi-

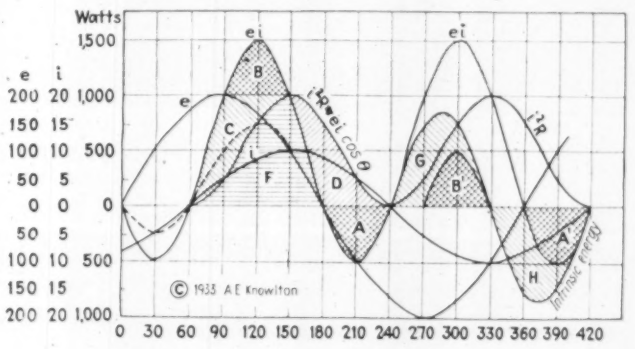
plied by their respective voltages to neutral; and, unless exact balance conditions exist, the results are likely to be confusing and inconsistent.

The most satisfactory method of indirect determination of volt-amperes is to combine the active and reactive components geometrically, by obtaining the square root of the sum of their squares; and the result of this computation is in agreement with the generally accepted definitions of volt-amperes, power factor and kindred magnitudes. In the use of integrating meters it is customary to obtain watthours on one meter and reactive volt-amperes on another, and, from a combination of the readings, to compute a quantity known as "volt-ampere-hours"; but as the relation between the two metered magnitudes may vary considerably during the time interval between consecutive readings of the meters, the significance of the combination is more or less indeterminate.

There have been developed a number of instruments and methods for the direct determination of volt-amperes, some involving geometrical combinations of active and reactive components by either mechanical or electrical computation, and others depending upon a shift in the voltage of an instrument of the wattmeter type, keeping the equivalent voltage applied to the instrument in phase at all times with the line current, or by shifting the voltage through an angle corresponding to that whose cosine is represented by the power factor of the load.

6. Metering of the Negative Power Loop.*

Reference to Fig. 30-14, February article on "General Principles" shows that the effect of a lowering of the power factor of a load is to give a certain portion of the power wave a negative significance, this portion being directly related in magnitude to the component of the volt-amperes which oscillates in a system and may be looked upon as being "borrowed" for purposes of mag-



A sinusoidal voltage, e, sustaining a sinusoidal current i through a series circuit of inductive reactance and non-inductive resistance so proportioned as to make i lag e, in this instance by 60°. There are three realities here, the voltage, the current and the instantaneous energy flow at the receiver terminals. Within the receiver there are two other realities—(1) the storage in and recovery of energy from the magnetic region which constitutes the inductance and (2) the conversion of the energy in the receiver into heat, mechanical work, light, etc.

Often obscured by the too-ready acceptance of the vector concept of reactive volt-amperes is the fact that, although during the period from 60° to 150° the receiver is here getting energy from the line, the energy is not being converted into heat, light or work as fast as it is being delivered to the receiver. While $e \times i$ during this interval exceeds i^2R, energy is being stored in the magnetic field of the inductance. This is represented by areas $B + C$.

After $e \times i$ declines to equality with i^2R (at 150° in this instance of 60° lag), the energy being converted in the receiver is sustained by a transfer of energy D from the quantity stored in the inductance. This quantity D, identical with C, *does not return over the line to the generator.* After the initial transfer of this energy from the generator to set up the magnetic field it oscillates within the confines of the receiver, between its energy-converting and its energy-storing components.

Fig. 35-11. Measurement of the negative power loop (Knowlton).

netization of inductive equipment. On this basis there has been developed a scheme of power factor measurement in which, by means of rectifying instruments, a measurement is made of the "negative power loop." While this system has not as yet received wide acceptance, it is worthy of study and of comparison with existing systems. The basic principle of this measurement is shown in Fig. 35-11 and the caption thereto, abstracted from the Electrical World and reprinted by kind permission of the author, Professor A. E. Knowlton.

*REFERENCES
V. Karapetoff. U. S. Patent No. 1,657,262, Jan. 24, 1928.
A. E. Knowlton. *Electrical World*, Jan. 28, 1933, page 130.
A. A. Bolsterli. *Electrical World*, Feb. 25, 1933, page 270.

B216 **Thermometers.** 28-page catalogue of thermometers entitled "Blue Book, Part 1, for science and industry for accurate temperature reading." H-B Instrument Co., Inc., Philadelphia, Pa.

B217 **Glue & Gelatine Tester.** Small leaflet gives a description and instructions for use of Jones' glue tester. Thwing Instrument Company, 3339 Lancaster Ave., Philadelphia, Pa.

B218 **Galvanometers.** Bulletin Galvo 33, a 24-page bulletin illustrating a number of galvanometers manufactured by P. J. Kipp & Zonen, Delft, Holland.

B219 **Manometers.** Bulletin No. 6 is a manometer price list. Bulletin R-392 illustrates the *clean-out* manometer. The Meriam Co., 1955 W. 112th St., Cleveland, Ohio.

B220 **Shadow Tuning Instrument.** Catalog Section 43-345 describes a novel resonance indicator for radio receivers. Designed for sets with automatic volume control; substituting the eye for the ear which is ordinarily not a very good guide to proper tuning on such sets. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

B221 **The Educational Focus.** The May 1934 issue of this periodical contains the following: Three Hundred Lashes for the Hellespont; Test Objects for the Microscope; Hunting the Fire-Bug with the Microscope; Glass Models of Microscopic Forms of Life; Photography in Office Practice, etc. Bausch & Lomb Optical Co., Rochester, N. Y.

B222 **Level Controller.** Bulletin 1085 illustrates the Tag uniflow level controller. C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y.

B223 **Practical Noise Measurement** is the title of a 4-page circular on the RA-138 noise meter. Electrical Research Products, Inc., 250 West 57th St., New York, N. Y.

B224 **Portable D.C. Instruments.** A new publication describing high accuracy portable instrument useful for laboratories, schools, test departments, etc. The six-page publication is well illustrated and describes the application, construction, operation of the new Px-5 instruments. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

B225 **Stabilflo Valves.** 4-page bulletin describes this valve designed for use with air-operated control instruments. Foxboro Company, Foxboro, Mass.

B226 **Thermostatic Steam Traps.** 4-page bulletin illustrates construction of this trap. C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y.

B227 **Time Controls.** 1-page leaflet gives data on the Type G Series of Paragon time controls on any electric circuit not exceeding 1600 watts. Paragon Electric Co., Old Colony Bldg., Chicago, Ill.

B228 **Combined Telescope & Magnifier.** Leaflet illustrates a pocket telescope magnifier. As a telescope it has a power of 2.5 and a real field of 7° 30'. As a magnifier it has the comparatively high power of 6X and is achromatic. Bausch & Lomb Optical Co., Rochester, N. Y.

B229 **Photocell Data.** 24-page 8½ x 11 booklet "Technical Data—Weston Photronic Cell," revised May 1, 1934, contains thorough discussion by W. N. Goodwin, Jr., and 9 full-page graphs with a total of 40 curves of characteristics, making it the most complete technical description of a photocell ever released to the public. Weston Elec. Instr. Corp., Newark, N. J.

B230 **Switches.** The Switch and Panel Division of the Square D Company, Detroit, Mich., are issuing new catalog pages for their large loose-leaf Catalog No. 37. About 160 pages, a number of which are entirely new, are being distributed. These will bring the catalog completely up-to-date. The catalog includes prices and descriptions of a complete line of switches, fuse cabinet and switch combinations, circuit breakers, Saflex panels, lighting and industrial circuit breaker panels, switchboards, meter boxes, Square Duct, RectiFilteRs and other equipment.

B231 **Measurement of Shaft Horsepower.** Bulletin 270 describes the Maihak torsionmeter for measuring the shaft horsepower on board ship. Bacharach Industrial Instrument Co., 7066 Bennett St., Pittsburgh, Pa.

B232 **Tempering Furnace.** Bulletin L-940 illustrates a Homo-tempering furnace specialized for high production on extra-dense loads. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

(Continued on Page 152)

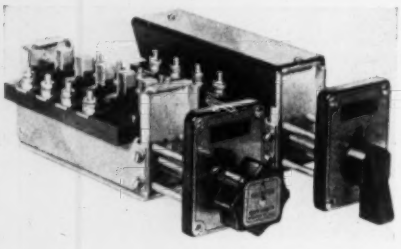
NEW INSTRUMENTS

Write Information Section, Instruments Publishing Company, for additional information.

Rotary Switches

Roller-Smith Co.

INSTRUMENT and control switches of modern construction, designated "Type R Rotary," are said to be used extensively on switchboards and control panels of all kinds. The instrument switches are used in connection with electrical measuring instruments and the control switches are used for establishing proper connections to air and oil circuit

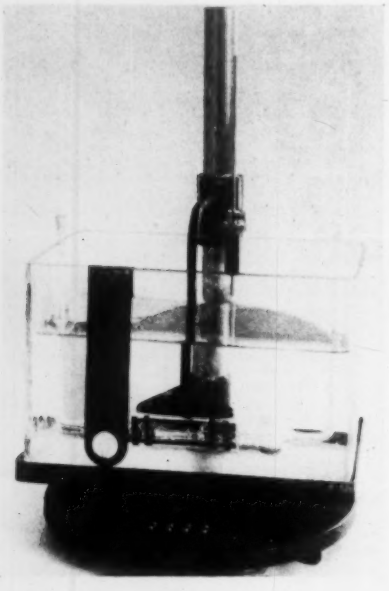


breakers and other equipment of that nature. Special attention is called by manufacturer to the fact that this new line has been worked out to provide a switch for every known requirement. These switches are said to be sturdy and compact and as nearly fool-proof as it is possible to make apparatus of this kind.

Magnetic Gas Balance

R. Fuess, Inc.

TO determine the molecular weight or specific gravity, respectively, of gases; or to analyze gas mixtures rapidly, are purposes of this new instrument. Its principle is measuring the buoyancy of a hollow quartz ball attached to a scale beam, which is a function of the density of the surrounding gas. The scale beam, into which is fused



a thin bar-magnet, carries at its other end a counterweight in the form of another hollow, but open quartz ball, whose total surface is approximately the same as that of the lifting ball, to compensate for the possible adsorption of gas. The balance, mounted on steel points resting in agate bearings, is enclosed in a glass box with a sliding top and provided with gas inlets and slides. Underneath is located a non-ferrous and therefore hysteresis-free electromagnet which has the purpose to react magnetically on the balance. *Procedure:* The balance casing is filled with the gas to be tested. Thereby the equilibrium of the beam is destroyed. The balance is then adjusted to zero again by means of a current through the electromagnet windings, measured by a milliammeter, the reading of which is then compared with a calibration curve previously determined with a known gas such as dry air. This density reading is then reduced to normal atmospheric pressure and 0°C. without calculation by using simple nomograms which are furnished with the balance.

Type 706 Precision Dial

General Radio Co.

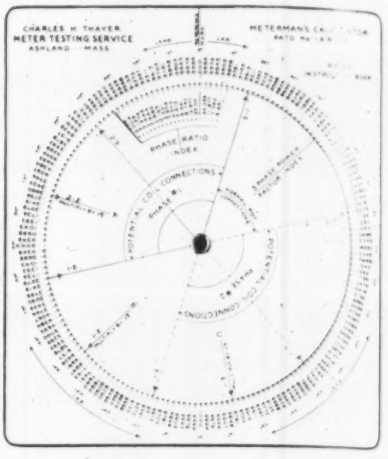
THIS new line of slow-motion dials is of interest to the experimenter and instrument maker. Scales are individually machine engraved. Slow motion is

so arranged that drive knob rotates in same direction as scale. Dials are available in 4" and 6" diameters and with 180° and 270° scales. A convenient auxiliary device is Type 519 Dial Lens which permits accurate reading and setting of the dial, as well as reading at a distance.

Meterman's Calculator

Charles H. Thayer

RESEMBLING a circular slide rule, this new device consists of two parts, a rotor and a stator. Index marks on the periphery of the former register with graduated scales on the latter. One of the stator scales is graduated in terms of the ratio of readings of a 2-element wattmeter or watthour meter connected on a balanced 3-phase 3-wire load, and the other scale in power factor values. An index on the rotor being brought into alignment with the value of the ratio, as determined from readings on the individual meter elements, the power factor of the 3-phase load, and that in the elements of the wattmeter, may be read on the power factor scale. If the wattmeter is known to be correctly connected, according to

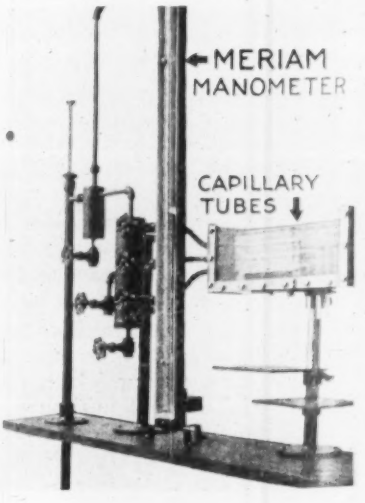


any one of several possible arrangements, an indication of load power factor and of current and voltage relationships in the measuring circuits is thus obtained; while with an approximate knowledge of load conditions, it is possible to detect erroneous metering connections, to correct for the errors so introduced into the wattmeter readings, and to rectify the wiring with a minimum of "juggling." While not specifically intended for use on 4-wire systems, the device is in some cases adaptable to computations on balanced circuits where the current transformers are wired in delta and the voltage transformers connected to the neutral point of the system.

Paint Viscosimeter

The Meriam Co. & The Glidden Co.

AN unusual use for its manometers is reported by The Meriam Company in connection with a new device designed by The Glidden Co. which enables the body or viscosity of paints, varnishes and lacquers to be determined without the need for more than a small test quantity. Small vials or test-tubes of the materials are first placed in a pump-circulated oil bath till they attain a predetermined temperature. Each in turn is then connected to a standard capillary suction tube which is maintained at a constant degree of vacuum by means of the manometer. As the paint or varnish is drawn up the tube, note is taken of the time required for the head of the column to pass from one scale mark to another. Three standard capil-



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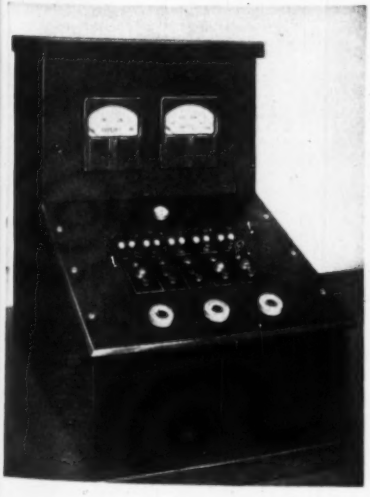
lary tubes are provided so that materials of widely differing viscosities may be readily tested. It is stated that this new method is not only quicker but more accurate than the usual tests.

Supervisory Control

Westinghouse Elec. & Mfg. Co.

FOR remote operation of various small stations "Polaricode, Junior," is a small size supervisory control including a raise-lower control combined with simultaneous telemetering indication of position for distant control of variable-position apparatus such as valves, rheostats, tap changers, etc. It has been designed and priced for application to small transformer switching, distribution and tie-point substation; various single-unit automatic railway, mining and hydro stations; electrified pumping stations; industrial plant substations, etc. Except for size, the new unit is comparable to all Westinghouse supervisory control systems. It operates a maximum of five apparatus units. Only two telephone-type line wires are required between the dispatching point and the remotely controlled station. The dispatching cabinet is but 14" wide, 21" deep and 20" high.



Industrial pH Meter

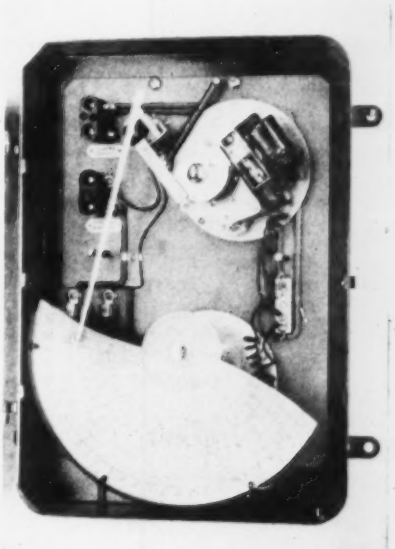
Thwing Instrument Co.

COMBINING in one portable outfit *all* the equipment necessary for making a pH determination by electrometric methods, this new instrument contains in compartments both antimony and quinhydrone electrodes and the vessels and chemicals necessary for their use. In designing it the makers strove for a tool to fit the job: which would combine simplicity of operation with a wide range of application; have sensitivity sufficient for most purposes and yet be rugged enough for portability. The circuit used is potentiometric, no current being drawn from the electrodes. Readings are directly in pH units on a hand calibrated 4" dial. Scale is readable to 0.02 pH. Galvanometer will stand ordinary bumping around, yet is sensitive to 3 megohms. No standardization or balancing is necessary before reading, the indications not being affected by changes in dry cell e.m.f. No change of connections is necessary when voltage relation of electrodes changes from plus to minus—a double pole, double throw switch being used. With quinhydrone electrodes, useful range is 0 to 8.5 or 9 pH; with antimony electrode it is 2 to 12 pH. Determinations are unaffected by color or turbidity of solution. Arrangement of electrodes is such that temperature error is ordinarily inappreciable. By incorporating a high-sensitivity galvanometer in the electrode circuit the instrument can be used with glass electrodes, extending its applicability to bleaching solutions, etc.

Spiral-record Electrical Operation Recorder

The Bristol Co.

PROVIDING a long record on a fast moving round chart, this instrument, instead of making one circular record, draws a spiral starting at the outer edge and gradually moving toward the center. This spiral record is accomplished by a Telechron-driven cam which continuously resets the record-making movement. This instrument is said to be meeting favor in time study work since it provides an open record with the easy filing and ready reference characteristics of the round chart. One form is fitted with a chart-driving clock making one revolution per hour and with a separate Telechron-driven cam making one revolution in 8 hours. The resulting record is a spiral covering 8 rotations of the chart with approx. $\frac{1}{4}$" spacing. The operation recording mechanism is a small electromagnet, energized when an external circuit is closed, which moves the inking pen approx. $\frac{1}{16}$". The entire movement is housed in the makers' moisture-proof rectangular Model 40M case.



Maihak Torsiometer

Bacharach Industrial Instrument Co.

MEASUREMENT of shaft horsepower on board ship is the purpose of this new instrument. The torsion element (Fig. 1) consists of two split sleeves rigidly clamped on the shaft at a distance apart of about 15" and each provided with a projecting arm. A hard alloy steel cord about 5" long, stretched between these arms in a plane normal to the shaft axis, is set vibrating by an electromagnet and in turn sets up

Fig. 1

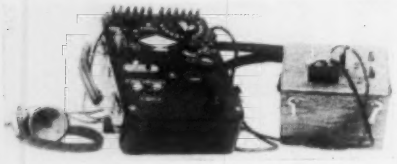


Fig. 2

an alternating current the frequency of which varies with its tension. This a.c., through slip-rings and suitable connections, is heard in the earphone of the receiving set (Fig. 2). This includes an adjustably-stretched comparison cord which is tuned to the same pitch as that of the torsion element—no musical ear required—whereupon the tension is read and, by reference to a table, the shaft torque. Then, by reference to the reading of a magnetic revolution counter (standard equipment) the shaft horsepower is determined.

Photoelectric Relay

G-M Laboratories, Inc.

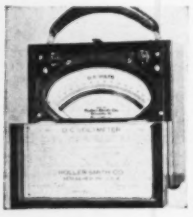
USING the Visitron F2 photocell which operates without external source of voltage and without amplification, this new unit incorporates also a sensitive relay and an auxiliary electromagnetic relay, housed in a cast aluminum

case 6¼" × 5 5/16" × 4". The cell can be mounted behind a glass window in the front of the case or hundreds of feet away from the sensitive relay. The unit can be completely weatherproofed. It can be used in locations not served by electric power lines and it is claimed that since there are no tubes to replace it will operate for long periods without attention. The cells, the auxiliary relays, or the two relays in combination can be supplied either assembled or individually as required for various electrical or photoelectric applications.

Portable Instruments

Roller-Smith Co.

TWO new lines, Types "NPD" for d.c. and "NPA" for a.c., are announced for general testing purposes, and also for use "as secondary standards where ruggedness and reliability combined with moderate cost must be considered." Such suitability as secondary standards has been made possible by incorporating refinements called for in exacting government specifications. Both



lines have same size and style of case, so that a laboratory can standardize test benches, racks, leads, etc. and simplify storing and handling. *D.C. Type NPD:* Two-part case, outer walnut and inner 2-piece iron, providing magnetic shielding, protecting mechanism from external strains and from dust and moisture. Improved d'Arsonval movements with tungsten steel magnets, highest-grade sapphires, specially-aged springs, etc. Hand-drawn scales 5¼" long. Accuracy ⅓ of 1% in normal (horizontal) position and ⅔ of 1% when stood vertical. *A.c. Type NPA* generally matches the d.c. line. Ammeters employ electromagnetic measuring elements; voltmeters, wattmeters and power factor indicators employ electrodynamic elements. Accuracy certificates same as d.c. line.

Laboratory Furnaces & Oven

Harold E. Trent Co.

METALLIC *Wound Furnaces* are announced for temperatures up to 2450°F. One has been designed for checking thermocouples, and has a long area of even heat. Standard laboratory and box type furnaces can now be obtained for temperatures up to 2400°F., optionally provided with piping for hydrogen atmosphere for metallurgical laboratory research.

In the new *Electric Oven* (inside dimensions 2' x 2' x 4') a circulating fan keeps the air at an even temperature, which is controlled by means of precision thermostats. Electrical heating units are placed on a two-part shelf and can be drawn out from either end of the oven. They are in two banks, each bank controlled by a thermostat. The whole equipment is self contained. Sides and top wall are pressed asbestos; bottom is steel-lined so that work may be moved in and out without injuring surface. Rating is 2.5 kw. at 220 volts.

"Faratron Invisible Control"

Lumenite Electric Co.

SAID to be a "new electromagnetic device," this unit has an antenna sensitive to dielectric changes in surrounding space, so that the approach of a human body, for example, causes a capacity change sufficient to trip the relay. Relays are available for operating burglar alarms, door openers, etc. Sensitivity is adjustable: at maximum, approach causes operation; at minimum, nothing happens until antenna is touched.

The Vapometer

Thwing Instrument Co.

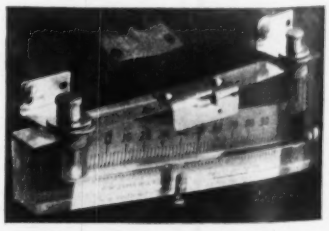
CONFUSION prevails in respect to *water-proofness*, the ability of wrapping papers to withstand actual drops of liquid water, and *moisture-proofness*, ability to withstand passage of invisible water vapor. A sheet may have excellent waterproofness and yet poor moistureproofness, or the reverse may be true. Uncoated transparent cellulose acetate sheeting is admirably

suited for wrapping wet products but it does not have much resistance to moisture. On the other hand coated viscose sheeting does not stand up satisfactorily for wet wrapping but has high resistance to moisture. Resistance to the passage of air is no criterion of moisture-proofness. Example, the comparison of plain and coated viscose sheeting: both have about the same resistance to the passage of air and yet the plain sheet will permit the passage of moisture at nearly 100 times the rate of the coated sheet. Until recently no test for moisture-proofness has been proposed which was quick and reliable, and which yielded data comparable among different testers. The Vapometer is said to fill this need. *Method:* Aluminum body is partially filled with water. Test sample is clamped between stationary rim and loose rim. Instrument is weighed and set before an electric fan at a distance that will give an air velocity of 600 to 700 f.p.m. At any time after six hours exposure, and at other time intervals, the Vapometer is again weighed. Results are expressed in "Water Vapor Transmission Rate" in "grams per 100 sq. in. per 24 hours." The Vapometer is designed to fit on an analytical balance, to make weighings convenient.

Transparent Draft Gages

F. W. Dwyer Mfg. Co.

BOTH inclined-tube and vertical-tube gages are announced, the body consisting of one block of 1" thick transparent Bakelite. Vertical types include both single-tube with reservoir and U-tube with equal-bore legs, so that the range of new line is greatly extended.

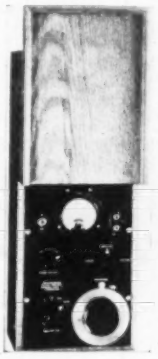


Portable instruments have L-connector for rubber tube; permanently-mounted instruments are usually supplied with flexible metallic tubing with ends sweated on with compression fittings for connector at gage and ⅛" s.p.t. at terminal end. Air filter gages are equipped with one 3-way cock at each opening, two 5-ft. lengths of aluminum tubing and static tips.

Type 544 Megohm Meter

General Radio Co.

FOR the measurement of insulation resistances of all low-voltage apparatus, of cables and of insulation samples, this portable instrument of the visual-indicating-bridge type is adapted to the measurement of resistances between 10,000 ohms and 10,000 megohms. The instrument is direct reading over this range and has a total scale length of 44". The additional galvanometer sensitivity which has made possible the construction of this type of bridge in a portable form with a self-contained galvanometer was obtained by the use of a vacuum-tube amplifier in the bridge-detector circuit. The new megohm meter is designed to be used either with battery or a built-in (60-cycle 115-volt) power supply. The 2-decade dial is individually engraved with an approximately logarithmic scale, thus giving same precision of setting over entire range. Mounting is in shielded oak cabinet. Dimensions with cover closed, 22½"x 8½"x8".



Type 505 Mica Condenser

General Radio Co.

FILLING a need both as a laboratory standard and in the construction of instruments where accuracy and permanence of capacitance are important features, the new Type 505 Condenser employs several unusual design expedients said to result in great long-time stability. Not only is it compensated for temperature changes but it is also immune to changes in moisture content of the surrounding air. Available in capacitances ranging from 100 $\mu\mu$f to 0.05 μf. Net weight 4 oz. Mounting is in low-loss Bakelite cases. Dimensions, 2¾"x 1 5/16"x1" overall.

Liquid Level Control

The Swartwout Co.

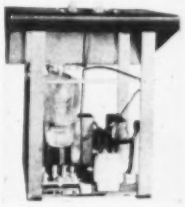
CONTROLLING liquid level in tanks, condensers, receivers, and other vessels, this new automatic device is characterized by what is said to be a unique feature: the float chamber is

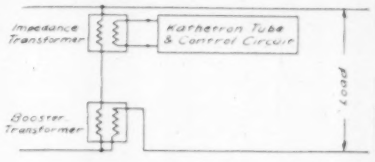
equipped with full ball bearing construction of stainless steel balls and races. This eliminates friction caused by liquid under pressure. The new controller will operate valves at any distance up to 300 feet and construction permits pressures up to 450 lbs.

Out-voltage Regulator

Roller-Smith Co.

BASED upon an electronic tube known as the Kathetron which has characteristics radically different from those of any other electronic device, the new Kathetron Out-voltage Regulator is especially suitable for limited capacity distribution lines, customers' premises and industrial applications where input line voltage is reasonably constant, but where an objectionable delivered voltage drop is caused by the starting of motors or by other relatively heavy sudden demands. If properly applied, it eliminates all visible light flicker. It is a completely-enclosed device (photograph shows essential parts removed from housing). Essentially it consists of a booster transformer, an impedance transformer and a Kathetron tube control unit (see diagram). A patented circuit making use of reflected impedance causes the Kathetron grid voltage, which varies in relation to the load, to control the output of the booster transformer. Maximum time delay which may occur is within a half-cycle, so that there is no light flicker even in an industrial plant where spot welders throw large loads on and off—an application where motor-driven voltage regulators are of no use. The new regulator can be used with widely different power factor loads by an adjustment in the device. It is designed to handle loads from zero to full rating, but an adjustment makes it possible to select some particular portion of the range for closest voltage regulation. Life is unlimited except for the 1000-hour tube.

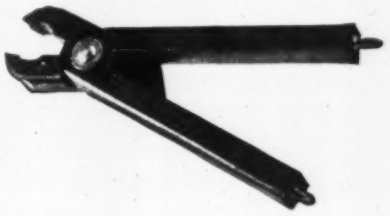




Electrician's Combination

Ideal Commutator Dresser Co.

MADE of reinforced Bakelite and resembling a pair of pliers, the Ideal Combination Test-Lite and Fuse Puller is a combination tool for testing, removing or inserting fuses from 30 to 100 amp. capacity, testing circuits to 550 volts, handling live electrical parts,

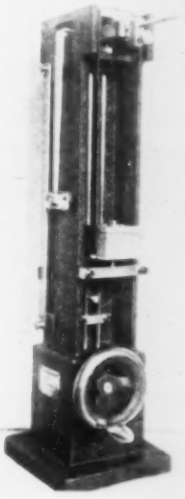


adjusting loose cut-out clips, etc. Test pins are mounted on handle ends: opening or closing handle adjusts pins to proper distance. Test light is enclosed in the handle. Overall length is 7".

Spring Testing Machine

Coats Machine Tool Co.

FOR accurate compression and extension tests of light springs, such as typewriter, adding and vending machine springs, "Elasticometer Type RS-5" combines a tensioning device with a scale for "weighing" the spring load and a graduated vertical length scale for measuring spring length. These three fundamental elements for static spring inspection are built into a cast-iron frame and result in a handy and accurate spring testing machine of clean-cut lines. *Drive* consists of a hand-wheel-operated rack and pinion. Directly attached to rack are upper compression plate, lower tension hook, and the pointer provided with a vernier. Stroke of rack may be set to automatic stops, in either direction. These stops speed up rate of quantity inspection, enabling operator to inspect 800 springs per hour. A lock-nut is provided for clamping rack in any desired position. *Weigher Scale* consists of a single 1 : 1 beam. Lower compression plate and upper tension hook are suspended from one end of this beam; loose weights from the other. Lower compression plate is guided in steel balls free to slide in vertical slots (to counteract forces operative at right angles to axis of a compression spring under load). Arrangement permits free play of beam in zero or balance position. A pointer attached to the beam magnifies errors four times in the spring being tested. This pointer can also be used for indicating deviations in terms of load. Rubber buffers protect scale against shocks as may occur when hard springs are suddenly loaded or unloaded. Both sides of Vertical Length Scale being graduated, it may be readily reversed when changing from compression to tension tests. The scale may be graduated either in 1/16" (with vernier reading in 1/128") or in decimalized inch graduations of 0.05" (with vernier reading in .01"). *Specification*: diameter of compression plate, 1¾"; maximum free length of compression springs and extended length of extension springs, 12"; total height, approx. 23"; net weight including standard accessories, 46 lbs. Machine is built for a normal load of 5 lbs.



PRECISION ANEMOMETERS

Contact, Cup and Vane types
Capable of Measuring Currents low as .02 meters/sec.

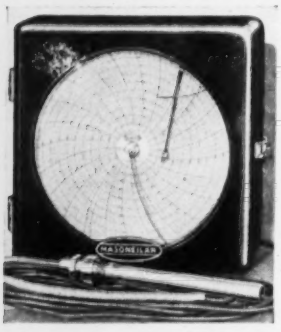
R. FUESS, INC.

245 W. 55th STREET NEW YORK
Est. 1865

Recording Thermometer

Mason-Neilan Regulator Co.

EMBODYING advanced design and construction, this new recorder is furnished in an attractive square Duralumin case with chromium plated hinges and hasp. It is equipped with

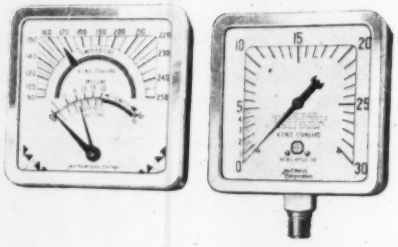


floating coil clamp which, it is said, eliminates friction and lost motion by permitting the coil to expand freely—radially and axially—so that only its angular deflection is transmitted to the pen-arm, thus increasing sensitivity and accuracy. These instruments may be equipped with the distinctive new "Over-Heat Protector" with which it is claimed that excess temperatures of 500°F. over the maximum chart range (of vapor-pressure systems) will cause no damage. Chart size is 12". Multiple-pen recorders are also announced. All parts are standardized and are interchangeable with other Mason-Neilan temperature control instruments. Among other features are a spring tension micrometer adjustment (pat. pend'g) for pen-arm, profuse use of 18-8 alloys, removable pen-arm and removable pen, etc.

Square Case Pressure and Combination Gages

Jas. P. Marsh Corp.

MODERN design ideas are embodied in the new cases in which the makers are prepared to supply their various types of pressure and combination gages. Any one combination can be produced, *i.e.*, combination thermometer and pressure and altitude gage, or compound pressure and vacuum gage

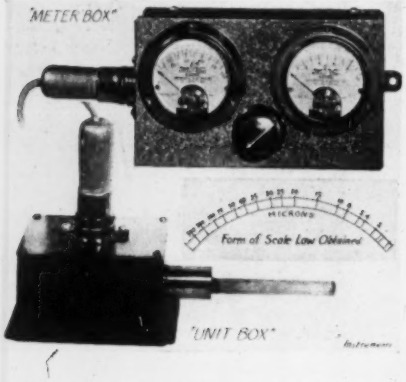


with or without retard feature. All of these can be supplied bottom- or back-connected, also (to boiler manufacturers) for flush mounting inside of the jacket. One size only: 3½" dial. A wide variety of finishes as desired.

Electric Vacuum Gage

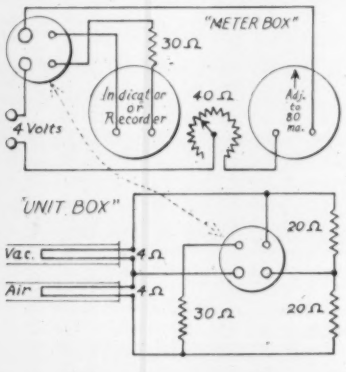
Continental Electric Co.

CONTINUOUS indications of vacuum are obtained by means of this improved model of the "Tru-Vac" gage. (Original model described in *Instruments*, Sept. 1931, page 518.) It consists of two units—a "unit box" and a "meter box." The *Unit Box* contains four elements, two fixed resistors and two glass



bulbs containing filaments—all connected in a bridge circuit. One of the filaments is kept at atmospheric pressure, the other is exposed to the vacuum being measured. The resistances are so proportioned that if the vacuum element is in a nearly perfect vacuum, the bridge is balanced. An increase in pressure on the vacuum element causes more heat to be conducted away from the filament, which lowers its temperature and resistance and thus unbalances the bridge.

The *Meter Box* supplies constant current to the bridge and reads the degree of unbalance of the bridge and hence the degree of vacuum in the system under test. It contains an ammeter and resistance for supplying constant current and a millivoltmeter for measuring the degree of unbalance of the bridge. Illustrations herewith present all essential details received from the manufacturer. Note: all resistances are approximate,



measured with an input of 80 ma. to the bridge circuit. The glass tube of the "unit box" is connected to the system and sealed either in rubber or to glass with vacuum cement. Electrical connections being by radio type cord-and-plugs, mistakes cannot be made when dismounting and re-assembling. When desired, connection is provided for either a recorder or a control relay as selected by user, or for both. Current supply may be a 4-volt storage battery or dry cells.

Compensated Smoke Recorder

Bailey Meter Co.

COMPENSATED for variations in light source intensity and operated by the "Galvatron" electronic relay circuit (*Instruments*, April 1934, pages 76-77), this new photoelectric smoke density recorder consists of a receiving element, Fig. 1, usually mounted on the individual boiler panel board, and of a transmitting element, Fig. 2, comprising projecting and detecting cylinders mounted on opposite sides of the breeching. A continuous record of relative smoke density is made on a 12" uniformly graduated chart. A hinged panel within the dust-proof pressed steel recorder casing carries the chart plate on one side and on the other side an easily accessible mounting for the sensitive galvanometer and electronic relays of the Galvatron. Two photocells are employed in the transmitting element,

Fig. 1

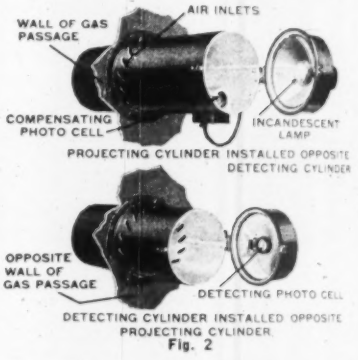
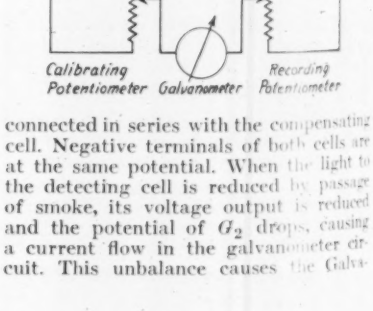


Fig. 2

one in the projecting cylinder and the other in the detecting cylinder. Full luminous flux from the light source is received by the compensating cell at all times, while the photocell in the detecting cylinder receives light of varying intensities, depending upon the density of the smoke in the passage. The method by which variations of light source intensity are compensated for is shown in Fig. 3: the calibrating potentiometer is connected in series with the detecting cell and the recording potentiometer is

Fig. 3



connected in series with the compensating cell. Negative terminals of both cells are at the same potential. When the light to the detecting cell is reduced by passage of smoke, its voltage output is reduced and the potential of G_2 drops, causing a current flow in the galvanometer circuit. This unbalance causes the Galva-

tron to move contact G_1 toward the negative terminal until a decreased voltage point is reached comparable to that of G_2 when no current flows in the galvanometer circuit. This movement of G_1, necessary to balance the potential of G_1 and G_2, is proportional to the smoke density by reason of the linear characteristic of the dry-disk self-generating photocell; and moving contact G_1 is geared to the pen which records relative smoke density on the uniform chart. Since intensity variation of the light source changes the output of each cell in the same proportion, the position of G_1 is determined by the *ratio* of light intensities received by the two cells. Thus, the true relative smoke density is recorded at all times regardless of voltage variations and loss of incandescent lamp efficiency.

Metal-clad Mercury Switch

Jefferson Electric Co.

FIELDS of application hitherto closed to mercury switches, by reason of fragility of glass, are opened up by these new switches for incorporation in manufactured products or for plant equipment. Six styles have already been announced; three types are illustrated: grounded type with one lead (Fig. 3) or with two leads (Fig. 1) and two-lead insulated type (Fig. 2). No fragile material is included in construction. Outer casing is made of drawn metal and in the non-insulated type the case is used as one of the electrodes. Casing is specially selected grade of iron which prevents amalgamation. Its outer surface is

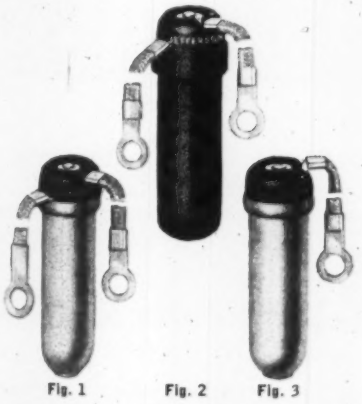


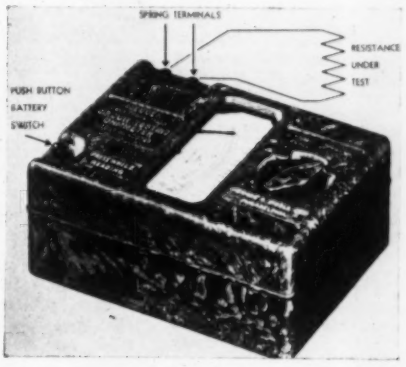
Fig. 1 Fig. 2 Fig. 3

treated to prevent corrosion and provide lasting contact surface. A second contact is mounted in an "unbreakable shock-resisting" porcelain insulator. Center contact is of same grade of iron as outer casing and has a stem protruding through insulator to form binding post. Insulator which supports center contact and insulates it from outer casing is formed to insure mercury-to-mercury contact, so that current is made and broken through mercury, preserving metal parts from damage. Casing is highly evacuated and then charged with inert gas under pressure, to quench arc and insure cool operation. Among other claims are: No possible danger to operator through breakage while mounting or handling; no possibility of open arc due to breakage; seal will withstand action of time indefinitely; switch may be stored without possibility of losing its full effectiveness; no radio interference; withstand severe electrical overloads without damage.

Midget "Megger" Circuit Testing Ohmmeters

James G. Biddle Co.

THESE are direct-reading instruments for quick measurements of resistance, from a fraction of an ohm to 200,000 ohms. Suitable for checking coils, rheostats, fixed resistances, etc., they provide also means for testing continuity of circuits, and — within their range — insulation resistance. They are similar in size and appearance (except for color) to the Midget "Megger" In-

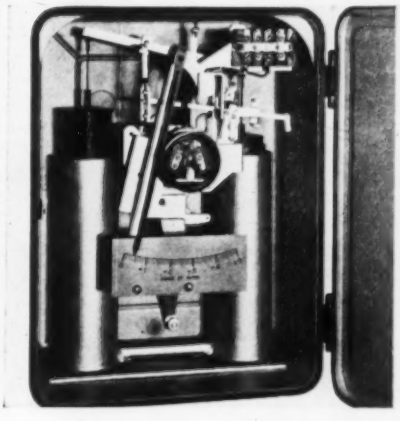


sulation Tester, brought out early last year (*Instruments*, March 1933, page 60). Readings are independent of variations in battery voltage, and no adjustments are necessary—one simply makes connections, completes the circuit (a push-button is provided), and reads the scale. The instruments have no binding posts, but instead have spring terminals for the testing leads. In order that the battery may be out of circuit except when tests are made, a push-button switch is available in either of two ways: on the instrument as illustrated, or incorporated in one of the hand spikes. With the latter method both hands can be free for manipulating the spikes or prods.

Anti-explosion Control Trip

Bailey Meter Co.

TO guard against explosive mixtures of fuel and air when lighting off pulverized coal, gas or oil fired boilers, this new device withholds fuel feed until boiler is thoroughly purged. Air flow through boiler is measured by two oil sealed bells suspended from a beam. A draft connection from right-hand bell to boiler furnace, and a similar connection from left-hand bell to last pass, utilize draft loss through boiler as a measure of air flow. Entire mechanism, including oil-



sealed bells, snap-acting contactor and indicating pointer, is enclosed in dust- and moisture-proof casing. Although device is provided with an indicating pointer for calibration and checking, its primary function is to operate the snap-acting contactor (seen in circular casing between bells) which is so linked to the air flow mechanism that it is necessary to run the rate of air flow through boiler up to approx. 60% of capacity before contactor snaps closed and permits operation of fuel feeder motor relay or control valve. Once this contactor goes to closed position it remains there until air flow value approaches zero.

Constant Temperature and Humidity Box

Thwing Instrument Company

DEVELOPED for testing the dielectric qualities of Bakelite and kindred substances, this cabinet has inside temperature maintained at 95°F. down to room temperature, with relative humidity at 90%. The humidifier, wet- and dry-bulb thermometers with electric contacts for controlling humidity, the circulating fan, electrical heater and indicating wet- and dry-bulb thermometers as well as the material to be tested are all included in a space 24"x24"x12". Electrical controls, said to be simple, rugged and reliable, regulate relative humidity and temperature closely.

"RA-138" Noise Meter

Electrical Research Products, Inc.

SINCE 1929 when Bell Telephone Laboratories built the first practical noise meter (which, however, required an entire truck and a crew of engineers) development has continued, now culminating in the portable RA-138 Noise Meter weighing 45 lbs. and contained in a 17" x 12" x 9"

case. Design affords equal accuracy of reading throughout the range. Readings are unaffected by severe jolts, vibration, and high acoustic fields. Built-in calibrating unit insures accuracy of reading at all times. Dynamic microphone insures proper characteristics, relatively free from vibration disturbance and wind noise. Wiring is arranged to withstand portable use. Small microphone, 2¾" in diameter and weighing 2 lbs. may be used with cord <200' long. Standard types of batteries and tubes may be used. One key connects indicator, one dial gives a rough setting before final reading. To calibrate, one switch is thrown. Should adjustment be required, one screw is turned.

Universal Instruments for Experimenters and Service Men

By F. S. Stickney*

ONE reason why universal instruments have been slow in coming is the great number of variables. Considering d.c. measurement alone, the ranges of commercial portable and switchboard ammeters extend from 0.000001 amp. to 10,000 amps. Even if we are satisfied with low accuracy (using our instruments between 10% and 100% scale) we will require 9 ranges between 0.000001 amp. and 10,000 amps. d.c. For better accuracy (changing at 33%) we require 21 ranges; and for best accuracy (changing at 66%) 57 ranges. Now double this number to cover d.c. voltmeters; multiply again by 2 for a.-c. work, and by 10 for various sizes and types, and we have 2280 electrical indicating instruments.

Another reason is the parallel growth of a.c. and d.c., requiring different principles of operation, different consumptions of energy, different scale laws, etc. A third reason is the complexity of shunts, resistors, thermocouples, transformers, etc., required for a complete line.

The copper oxide rectifier has removed a serious barrier. By its use, both d.c. and a.c. can be measured with the same d'Arsonval element designed for low consumption of energy. Electrodynamic and iron vane elements are applicable to both a.c. and d.c., but they require so much power that design of shunts and resistors becomes impossible in the upward direction, and wire diameters for coil windings become impracticable in the lower direction. So the Rectox instrument** is at present the most flexible of all, and multi-range combinations recently completed should prove attractive.

Universal Rectox Instrument. Greatest flexibility, at minimum cost, is found in the new Type NX four-scale Rectox instrument with a total of 34 ranges. Of the permanent-magnet d'Arsonval type, it has four terminals, two for a.c. and two for d.c. A small copper oxide rectifier is mounted inside the case, and a system of fixed internal shunts compensates for the current loss during rectification of a.c. As a result, the instrument reads full scale on 1 ma. either a.c. or d.c. according to the terminals selected. This permits use of the same resistance spools for measuring either a.c. or d.c. volts, an appreciable economy and a decidedly new feature. Fig. 1 shows the internal connections of the NX instrument. Resistance A is used for standardizing the resistance of the leg of the circuit which contains the moving coil. Resistance B is used for adjusting the calibration across the a.-c. terminals to 5 volts. Resistances R_1-R_2 are designed to correct for the ratio (d.-c. output/a.-c. input) of the rectifier. The value R_2/R_1 varies with different rectifiers and this variation is taken into account in calibrating the instrument in order to obtain a high degree of accuracy. The resistance of the instrument on d.c. is 100 ohms, corresponding to 100 mv. full scale at 1 ma. On a.c. the resistance is 5,000 ohms across terminals, corresponding to 5 volts full scale at 1 ma. It will be noted that the resistance of both a.c. and d.c. voltage ranges will thus be calculated on the basis of 1,000

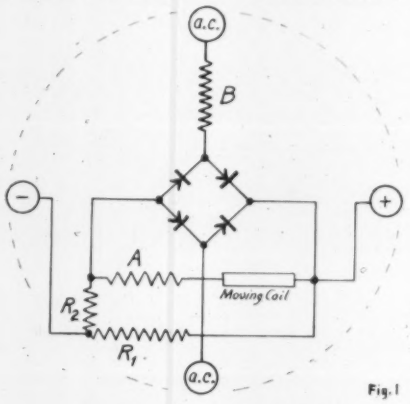


Fig. 1

ohms per volt. The instrument alone is thus self-contained for four ranges:

0-1 mv. d.c.	0-100 mv. d.c.
0-1 ma. a.c.	0-5 volts a.c.

Standardized accessories, Fig. 3 (A-D), of simple design, make it convenient to obtain other ranges as follows:

0-1-5-10-50-100-200-500-1000 volts d.c.
0-10-50-100-200-500-1000 volts a.c.
0-5-10-50-100-500 ma. d.c.
0-5-10-50-100 ma. a.c.
0-1-5-10-50 amp. d.c.
0-1000-10,000-100,000 ohms.

It is thus possible to get a total of 34 ranges with a single instrument having only four scales. The accessory resistances are arranged so that temporary connections can readily be made for taking occasional readings, or so instrument and resistances can be permanently mounted in a test box or panel with selector switches if desired.

Radio Frequency Ammeter. This is the newest example of the development of low-energy instruments. It meets the requirements of the radio amateur who desires to know the current in his antenna, and of the experimenter who desires a low-range d.c. millivoltmeter for measuring oven or other temperatures by means of a thermocouple. The new instrument is a d.c. millivoltmeter calibrated 0-10 millivolts with 4-foot leads. It has two scales (see Fig. 4) one linear for d.c. or for a.c. squared, the other an approximately square law scale for use with radio frequency thermocouples. An external radio frequency thermocouple unit, Fig. 3 (E), usable with this instrument, has five heaters of the following ranges:

0-1-2-5-10-20 amps. R.F.

Each heater has its individual thermocouple and leads, and all are standardized at 10 millivolts. This combination should prove especially useful in setting up new transmitters, oscillators, etc., where the probable current to be measured cannot be accurately predicted. The heaters are fully compensated against ordinary errors, and have unusually high overload capacity for this type of apparatus. The universal R.F. instrument has a resistance of 10 ohms and a full scale current of 1 ma. d.c. Its d.c. current characteristics are, therefore, identical with those of the Universal Rectox instrument, and the same accessories can be utilized for both instruments to a considerable extent. The following ranges can be obtained with the universal R.F. ammeter and standard accessories.

0-1 ma. d.c. }
0-10 mv. d.c. } Self-contained
0-1-2-5-10-20 amps. R.F.
0-0.1-1-5-10-50-100-200-500-1000 volts d.c.
0-5-10-50-100-500 ma. d.c.
0-1-5-10-50 amps. d.c.

The standardized accessories shown in Fig. 3 are as follows:

A. Combination shunt for d.-c. milliamperes.
B. Combination shunt for a.-c. milliamperes.
C. Combination shunt for d.-c. amperes.
D. Multiplier for a.-c. and d.-c. volts.
E. Multi-range thermocouple for amperes radio-frequency.

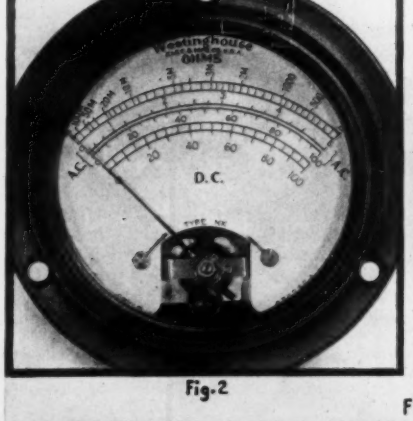


Fig. 2

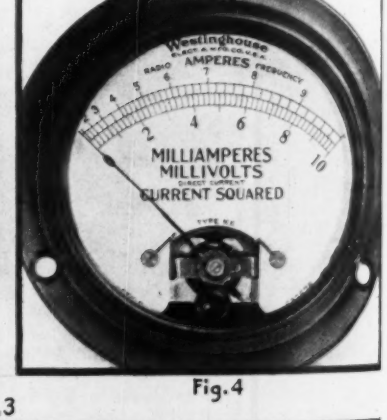
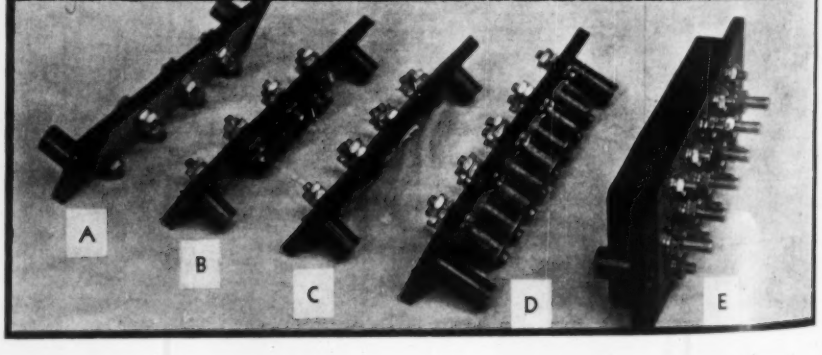


Fig. 4

Fig. 3



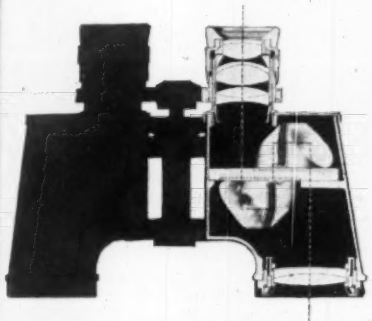
*Meter Engineering Division, Westinghouse Elec. & Mfg. Co., Newark, N. J.

**For detailed description of this type see article by B. R. Hill, *Instruments*, July 1933, page 149.

Improved Binoculars

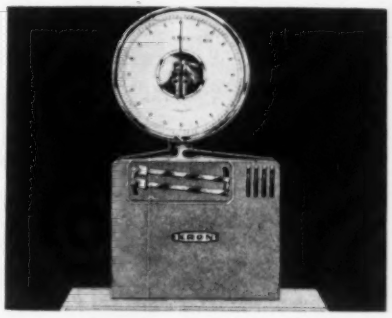
By Everett W. Melson*

IN their design, our new binoculars were influenced by the requirement of the U. S. Navy and the Coast Guard for a 7x50 mm. glass that would be waterproof and strong yet light in weight. A distribution of weight was achieved which locates the center of gravity in the area of contact with the hands, relieving wrist fatigue experienced by officers compelled to use glasses for long periods. This design met with a response which led to its introduction throughout the line. Bodies are aluminum die castings, with strap loops cast integral. To make glasses moisture-proof, cover on objective side (typical of most conventional designs), is omitted; other cover is waterproofed; and a hard-rubber covering with a leather grain is vulcanized directly to the metal body, forming a one-piece shell impermeable to moisture. Mounting of prisms represents a complete departure from usual practice. Instead of being fastened into recesses integral with the body, prisms are secured



to a separate plate which allows their extremely accurate adjustment *before* they are placed in the body. This construction makes prisms accessible from all sides for adjustment. Locating pins prevent shifting but permit removal of complete prism assembly for cleaning without interfering with optical adjustment. Since it is not easy to align optically all the elements that go to make up the optical system for a pair of binoculars, an adjustment is provided at the objective end. The outside surface of the objective mount is eccentric to the bore and this part is rotably fastened to an adapter, the bore of which is also eccentric to the circumference. Slots in spanner wrenches in both parts facilitate turning objective mount and adapter in relation to each other. This shifts the center of objective lens within a range sufficient to adjust all errors caused by slight discrepancies in manufacturing. Glasses are adjusted and tested until alignment of the barrels is correct to 1% from one extreme of adjustment to the other. Lenses and prisms must be accurate to within a wavelength of light of the specifications. Field of view is as large as possible without sacrifice of other desirable qualities. An adjustment of one eyepiece enables user to adjust center focusing glass to his own eyes and a scale enables him to reset them. Independently focusing eyepiece construction (available in all models) is preferred by the Government services because of its moisture-tight construction, simplicity and sturdiness.

*Bausch & Lomb Optical Co., Rochester, N. Y.



Cabinet Platform Scale

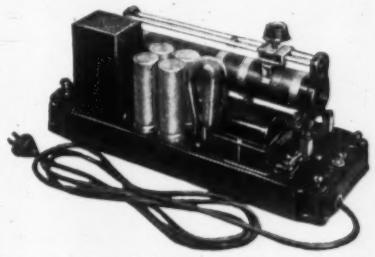
The Kron Co.

DEPENDING on the specifications, this new cabinet or unit weight type dormant platform scale comes equipped with from 1 to 4 unit weights, and is so arranged that by pressing down on the first handle a unit weight equal to the capacity of the dial is added to the weighing system. By pressing down the second handle a second weight equal to dial capacity is added; to add all 4 unit weights at one time, simply press down the fourth handle. The weight thus added is shown in a small window on the dial face. Principal use: weighing larger loads by small increments where it would be impractical to graduate the dial to the fine divisions necessary. The standard Kron free-floating platform is used in this assembly. Indicating mechanism is the improved Kron one-cam translation ball-bearing type.

Power Supply Unit

G-M Laboratories, Inc.

FOR furnishing thoroughly filtered direct current from 100-volt 60-cycle power lines, this new unit is rated to furnish 450 volts or less with a maximum direct current of 100 m.a. The



output of an '83 type full-wave rectifier tube is connected across the winding of a high resistance, wire wound Type L potentiometer (G-M) from which any voltage from 0 to 450 volts may be obtained in minute steps. The unit is provided with a lock which can be set so as to limit the voltage available at the terminals, for safety purposes.

Across-the-line Starter

The Electric Controller & Mfg. Co.

FOR motors up to 15 h.p., 220 volt, and 30 h.p., 440-550 volts, there is announced the EC&M Type ZO, Weather-proof and Dust-tight, Across-the-line, Oil-immersed Motor Starter. These starters are enclosed in a case which has been bonderized and then black enameled. When desired, a self-contained ammeter in a dust-tight case can also be furnished. The starter is arranged for remote control, push button automatic operation.

BOOK SHELF

(Concluded from Page 136)

matter and of the *electron*, in its most elemental aspects, without resorting to the higher mathematics that would be necessary in a detailed study. "A table giving the abbreviations for and values of physical quantities" is included in the first chapter and ought to serve a useful purpose.

Chap. II deals with "potential energy and capacity" as a preliminary to Chap. III on "electrons and ions," which treats the fundamentals again in an understandable manner. Here the subject is so competently handled that this portion of the book might serve very well as a text for average technical students. Chap. IV treats "charging and discharging bodies"—the elements of electricity. The next deals with "dielectrics and electric condensers." The illustrations in themselves make the properties of condensers with applied potentials easily understandable without one's reading the chapter.

Chap. VI covers "magnetic and electromagnetic effects," from the natural magnet, through the permanent, and thence to the electromagnet (a.-c. and d.-c.). Chap. VII is a more detailed study of alternating currents, their generation and their conversion into mechanical motion through motors. Direct current generators are discussed here as well.

Chap. VIII has to do with "space, time and oscillations" as a preliminary to the study of the generation of electrical oscillations in electronic tubes (Chap. IX). In this latter chapter we get a detailed study of vacuum and gas-filled tubes from the earliest development period to modern pentode tubes. Then the author takes up the circuit phenomena associated with electronic tubes, and next in Chap. XI gives a detailed study of the circuits of these tubes. Chap. XII on "electronic lamps" explains the "oscillating arc lamp" and then gives a summary of gas-filled lamps, their circuits and uses.

Different in scope is Chap. XIII on the "electronic age" which shows the commercial uses of the various types of tubes, lamps and circuits discussed previously. Chap. XV then shows how light and color behave under various conditions, and Chap. XVI discusses in general the different types of photoelectric cells, while Chap. XVII is a detailed study of "specific types of photoelectric cells." It starts with the common form of selenium cells, lightly touches the thalofide cell (thallium oxysulphide) of Case which earned a wide reputation several years ago, and next the photovoltaic cell, describing two commercial forms. The older form of alkali metal hydride and the conventional form of caesium oxide vacuum or gas-filled cell are next discussed, followed by the "barrier" or self-generating cell (cuprous oxide). It is interesting to note here that the use of cuprous oxide as a "photo conduction cell" was known as far back as 1896 (described by Mercadier) and re-discovered in 1916-1917 by Pfund; and that the achievement of Grondahl and Geiger discussed in the text as a self-generating cell was that they omitted the potential in the circuit merely by sheer accident in a study of the cuprous oxide plate as a rectifier. Note also that the "photronic cell" discussed in the text as belonging to this group uses selenium as the active material.

Chap. XVIII ("general methods of using photoelectric cells") shows just how cells may be used in various circuits for experimental and commercial uses and Chap. XIX gives an interesting survey of the cells and circuits already discussed.

A more advanced type of electron tube is discussed in Chap. XX on cathode-ray tubes, and the treatment then necessarily becomes more scientific in Chaps. XXI on "invisible light," XXII on "x-rays," and XXIII on "matter and energy," but these three chapters are nevertheless clear and readable.

As its title implies Chap. XXVI ("the electronic past and future") discusses in a prophetic vein what the future might bring. All in all, the book will prove valuable to the student or average scientific reader, but will find place also on the shelves of many serious workers in this most fascinating of scientific fields.

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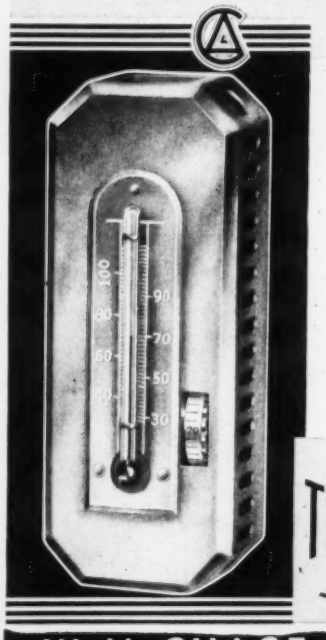

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Manufacturers' New Literature

(Concluded from Page 143)

B233 **Pyrometers.** Leaflet has illustrations of low priced pyrometers. Russell Electric Co., 340 W. Huron St., Chicago, Ill.

B234 **Solving Industrial Crimes.** 12-page booklet illustrating various instruments manufactured by Esterline-Angus Co., Indianapolis, Ind.

B235 **Switches & Controllers.** The Square D Company have just published a new Digest which is a condensed illustrated catalog of forty pages giving information and prices on nearly all products manufactured in both the Switch and Panel Division in Detroit and the Industrial Controller Division in Milwaukee.

B236 **Chromalox News.** Issue No. 3 has the following items: Steering Wheels Molded Electrically; Drying Time Cut 50%; Eliminates Losses by Baking Electrically; Portable Dipping Tanks Provide Quick Cleaning; Electric Pre-Heaters Cut Operating Costs in Sheet & Tin Mills. Edwin L. Wiegand Co., 7500 Thomas Blvd., Pittsburgh, Pa.

B237 **Bursting Strength of Paper.** Fly-leaf discusses paper bursting strength tests. B. F. Perkins & Son, Inc., Holyoke, Mass.

B238 **The Durez Molder.** The May issue of this publication mentions a number of applications of Durez. It is issued by General Plastics, Inc., North Tonawanda, N. Y.

B239 **Rheostats.** Ohmite Catalog 16, contains 8 pages of information on rheostats and resistance units. Ohmite Manufacturing Co., 636 N. Albany Ave., Chicago, Ill.

B240 **Boiler Concentration Recorder.** Bulletin No. 1434 describes the boiler concentration recorder and the condensate recorder. Esterline-Angus Co., Indianapolis, Ind.

B241 **Altitude Barometer.** 16-page booklet illustrates various barometers of the Taylor Instrument Cos., Rochester, N. Y.

B242 **Bakelite Synthetic Resins for Paints and Varnishes** is the title of a 24-page booklet which indicates the extremely wide variety of Bakelite resins which are available for the manufacture of specialized finishes. Bakelite Corp., Bound Brook, N. J.

B243 **Portable Gas Analyzer.** Bulletin 20 describes a new portable gas analyzer for flue gases manufactured by Ellison Draft Gage Co., 214 West Kinzie St., Chicago, Ill.

B244 **General Radio Experimenter.** The May issue of this periodical contains the following articles: How Dials are Made; New Sweep Circuit for the Electron Oscillograph; and Photography of Transients with a Cathode-Ray Oscillograph. General Radio Co., Cambridge, Mass.

B245 **Battery Charging Rheostats.** Bulletin 2501 is a 4-page bulletin on battery charging rheostats and resistors. Ward Leonard Electric Co., Mount Vernon, N. Y.

B246 **New Model Graphic Instrument.** Catalog No. 434 gives complete information on the Model A.W. instrument. This 84-page book illustrates the various types and cases available. Chapters cover: the chart drives, the measuring elements, special features and attachments, sale of instrument parts, clocks and supplies to other manufacturers, instrument specifications, accessories, supplies, inspection and trial test, instrument repairs and guarantee. Esterline-Angus Co., Indianapolis, Ind.

B247 **Hydrogen Ion Comparators.** Bulletin No. 600 described pH comparators with solid glass color standards. 24-page, 8½ x 11 size. Hellige, Inc., 179 East 87th St., New York, N. Y.

B248 **How to Select Insulated Cable.** A new 80-page reference book, GEA-1837, covers cable for the transmission and distribution of electric power at normal frequencies. Tables of wire gages and dimensions, sizes of shipping reels and a bibliography are included. General Electric Co., Schenectady, N. Y.

B249 **Determination of Viscosity.** Leaflet describes a portable instrument for measuring the variation of viscosity as affected by temperature (and dilution), and for checking the viscosity at any desired temperature. Visco-Meter Corp., 315 Grote St., Buffalo, N. Y.

B250 **Automatic Maximum Demand Controller.** Bulletin 534 discusses the reduction of the demand charge by reducing the demand. Esterline-Angus Co., Indianapolis, Ind.

B251 **Capacity Meter.** Leaflet describes a new portable, direct-reading multi-range microfarad- or capacity-meter. Jas. J. Biddle Co., 1211 Arch St., Philadelphia, Pa.

B252 **Incline Plane Serigraph.** 4-page bulletin contains data and tests made with this machine on commercial yarns. Henry L. Scott Co., 101 Blackstone St., Providence, R. I.

B253 **Wet Test Meter.** Leaflet TS3110 Sheet 4 gives data on the Precision-Sargent wet test meter and accessories. Precision Scientific Co., Chicago, Ill.

B254 **Sensatherm.** Bulletin No. 100 illustrates the mercoid sensatherm, an air type thermostat for low or high voltage applications. Mercoid Corp., 4201 Belmont Ave., Chicago, Ill.

B255 **Circuit Testing Ohmmeters.** Bulletin 1380 describes the Midget "Megger" circuit testing ohmmeters and illustrates its application. James J. Biddle, 1211 Arch St., Philadelphia, Pa.

B256 **Tensometer.** Leaflet illustrates interesting applications of Huggenberger tensometers. Baldwin-Southwark Corp., Philadelphia, Pa.

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Pressure-Temperature
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Pressure & Vacuum
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Profile
Rain
Taylor Instrument Cos.
Recording—Distance
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Strain
General Electric Co.
Pump
Bailey Meter Co.
Taylor Instrument Cos.
Water Wheel

GRAVITOMETERS
American Meter Co.
George Sidney Binckley
Thwing Instrument Co.

GROUND DETECTORS
Roller-Smith Co.
Weston Elec. Inst. Corp.

HAND TALLEYS

HARDNESS TESTERS

HIGH FREQUENCY APPARATUS
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

HIGH VOLTAGE
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Shallcross Mfg. Co.
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Measuring Devices
General Electric Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.
Testing Devices
General Electric Co.

HOUR COUNTERS
Weston Elec. Inst. Corp.

HUB ODOMETERS

HUMIDITY CONTROLLERS
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

HUMIDITY RECORDERS
Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.

HYDROGEN ION METERS

HYDROMETERS
Taylor Instrument Cos.

HYGROMETERS
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

ILLUMINOMETERS
Weston Elec. Inst. Co.

INDICATORS—See Gages

INDUCTANCES
General Radio Co.

INSTRUMENT CALIBRATION AND REPAIRS
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

INSTRUMENT TRANSFORMERS
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Roller-Smith Co.
Weston Elec. Inst. Corp.
Split Core
Roller-Smith Co.
Phase Shifting

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General Radio Co.
Roller-Smith Co.

MEGOHM VOLTMETERS
Roller-Smith Co.
Weston Elec. Inst. Corp.

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Rawson Elec. Instru. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

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Roller-Smith Co.
Weston Elec. Inst. Corp.

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Brinell
Gaertner Scientific Corp
Measuring
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Gaertner Scientific Corp
Metallographic
Bausch & Lomb Opt. Co.
Petrographical
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MICROTOMES
Bausch & Lomb Opt. Co.

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General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

MILLIVOLTMETERS
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Brown Instrument Co.
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

MIRRORS
Bausch & Lomb Opt. Co.

MODULATION METERS
General Radio Co.
Weston Elec. Inst. Corp.

MOISTURE METERS
General Radio Co.

MOTION RECORDERS
Mechanical
Bristol Company
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Roller-Smith Co.
Ward Leonard Elec. Co.

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Rawson Elec. Inst. Co.
Shallcross Mfg. Co.

MULTIPLE PEN RECORDERS
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Shallcross Mfg. Co.
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Taylor Instrument Cos

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Roller-Smith Co.

Electrical
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Foxboro Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.

OPTICAL PARTS
Bausch & Lomb Opt. Co.

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Bailey Meter Co.
George Sidney Binckley
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Foxboro Co.

Integrating
American Meter Co.

ORIFICES, ADJUSTABLE
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Bailey Meter Co.

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General Radio Co.

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General Radio Co.

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Weston Elec. Inst. Corp.

PHOTO-ELECTRIC COLOR ANALYZERS
General Electric Co.
Thwing Instrument Co.

PHOTO-ELECTRIC COLOR COMPARATORS
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Thwing Instrument Co.

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PHOTOMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

PHOTO-MICROGRAPHIC EQUIPMENT
Rawson Elec. Instru. Co.

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George Sidney Binckley
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Foxboro Co.
Pioneer Instrument Co.

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Brown Instrument Co.
Foxboro Co.

Linear
Brown Instrument Co.

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Bristol Company
Foxboro Co.

Square Root
George Sidney Binckley
Foxboro Co.

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Gaertner Scientific Corp.

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Bristol Company
Foxboro Co.
Taylor Instrument Cos.

POTENTIOMETERS—
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General Electric Co.
Thwing Instrument Co.

Recording & Controlling
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Thwing Instrument Co.

Standard Cell Comparing
Feussner Type

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Roller-Smith Co.
Weston Elec. Inst. Corp.

PRESSURE RECORDERS
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Bailey Meter Co.
George Sidney Binckley
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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

PRISMS
Gaertner Scientific Corp.

PROCESS TIMING & SIGNALING INSTRUMENTS
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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

PROVERS
American Meter Co.

PROTRACTORS
Optical

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Recording
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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

Sling
Taylor Instrument Cos.

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Weather Bureau Type

PYROMETERS
Optical

Radiation
Indicating
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Taylor Instrument Cos.
Thwing Instrument Co.

Recording
Brown Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.

Thermo-electric
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Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.

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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
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Thwing Instrument Co.

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REFRACTOMETERS

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Ward Leonard Elec. Co.
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Roller-Smith Co.
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Burgess Labs., Inc., C. F.

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Burgess Labs., Inc., C. F.

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Pioneer Instrument Co.

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Ward Leonard Elec. Co.

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Taylor Instrument Cos.

SALINITY INDICATORS

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Thwing Instrument Co.

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SHUNT METERS
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Roller-Smith Co.
Weston Elec. Inst. Corp.

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Pioneer Instrument Co.

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General Radio Co.
Pioneer Instrument Co.
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SPEED INDICATORS
See Tachometers

SPEED RECORDERS
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Brown Instrument Co.
Thwing Instrument Co.

SPEED REGULATORS
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Taylor Instrument Cos.

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Roller-Smith Co.

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Roller-Smith Co.
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Brown Instrument Co.

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Foxboro Co.

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Foxboro Co.
Thwing Instrument Co.

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Brown Instrument Co.
Foxboro Co.
Taylor Inst. Companies

Wet & Dry Bulb
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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.

THERMOSTATS
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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

THERMOSTATIC BIMETAL
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TIME INDICATORS

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Weston Elec. Inst. Corp.

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Foxboro Co.

TIME RECORDERS
Bristol Company
Brown Instrument Co.
Foxboro Co.

TIME SWITCHES
General Electric Co.

TIMERS
Rawson Elec. Inst. Co.

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TORSIOGRAPH

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General Electric Co.

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Gaertner Scientific Corp.

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General Radio Co.
Gaertner Scientific Corp.

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Taylor Instrument Cos.

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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

VACUUM TUBE BRIDGES
General Radio Company

VACUUM TUBE RELAYS
Burgess Labs., Inc., C. F.

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General Radio Co.
Rawson Elec. Inst. Co.

VALVES
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Taylor Instrument Cos.

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Taylor Instrument Cos.

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Taylor Instrument Cos.

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Taylor Inst. Companies

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Ward Leonard Elec. Co.

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Roller-Smith Co.

Indicating
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General Radio Co.
Rawson Elec. Instru. Co.
Roller-Smith Co.
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Recording
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Roller-Smith Co.

Thermionic Rectifier
General Radio Co.

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George Sidney Binckley
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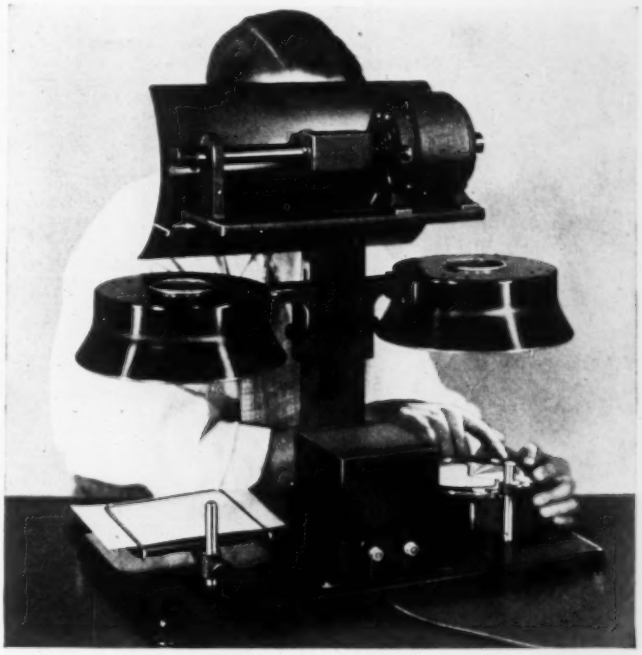

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